THE ACCEPTANCE AND USE OF AUGMENTED REALITY IN A MANUFACTURING ENVIRONMENT

by

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ABSTRACT

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In this study, the researchers illuminated the positive advantages of incorporating augmented reality (AR) technology into the daily practices of service engineers working in an advanced manufacturing environment. AR technology improved the user's communication with colleagues and content experts through real-time video conferencing and brought valuable information directly to the user on a mobile platform. This effective communication had the potential to reduce the time it takes to complete a work task, even when the user is in a remote location. However, it could not be assumed that people would be willing to use this new technology just because it was available. In order to promote the positive advantages of incorporating AR technology into the daily practices of service engineers, more research was needed to assess the user's perceived value of AR technology and their willingness to accept AR technology into their daily tasks. The purpose of this research was to demonstrate the advantages of using augmented reality technology to improve communication and access to information as well as to assess the acceptance and use of this technology based on the behavioral intentions of a trained engineer. Using that information and the Unified Theory of Acceptance and Use of Technology including its extensions (UTAUT and UTAUT2) (Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, 2012) this research determined if AR technology is viable for larger scale adoption.

CHAPTER 1. INTRODUCTION

1.1 Introduction

Augmented reality is a live view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. This projection of content can be accomplished using a smartphone, tablet, or head-mounted display (HMD). Augmented reality technology has been applied and tested, at the case study level, in multiple environments including the medical field (Sun, Tao, Hu, Fan, & Wang, 2014; Hou, Ma, Zhu, Chen, & Zhang, 2016; Servotte, 2017), educational field (Zarraonandia, Aedo, Diaz, & Montes, 2014; Pejoska, Bauters, Purma, & Leinonen, 2016; Sahin, et al., 2016) manufacturing environments (Elia, Gnoni, & Lanzilotto, 2016; Yew, Ong, & Nee, 2016; Uva, 2018), and even as assisted living technology for the elderly (Saracchini, Catalina-Ortega, & Bordoni, 2015). This thesis was focused on a manufacturing environment, although research collected from other fields were still relevant to this study

One commonly recognized HMD device is the Microsoft HoloLens. This device uses a series of voice commands and hand gestures to project information directly onto the user’s field of view so that it can easily be viewed during the completion of a task. The HoloLens is a very unique and advanced holographic computer, but industry professionals are hesitant to begin using it due to its high price, large size, and low battery life. (Fiorentini, Johnson, & Joseph, 2017) Many other HMD devices are essentially rudimentary versions of the HoloLens, using simplified methods to accomplish similar goals. This becomes advantageous because these simplified methods allow for the development of augmented reality applications that work with already existing iOS and Android platforms. This also allows developers to take advantage of the millions of applications already available on these platforms and view them from a new perspective. This thesis used, commercially available, AR hardware and software which allowed engineers to view instructions, document their work, and communicate with others via, real-time, video conferencing. This thesis hypothesized that a commercially available AR platform could be applied and generalized to assist a service engineer during their daily tasks of servicing and supporting a product in the field.

Traditionally engineers are required to use a computer multiple times while conducting maintenance services. Engineers need computers to access important information, to document their progress, take notes during a task, and to communicate with other engineers or experts. Currently, engineers must leave their workstation and walk a short distance in order to access a computer and complete these tasks. Additionally, engineers may have to complete excessive steps such as putting away tools or removing their gloves before they are able to use the available computer. This opens a window for mistakes to be made or for information to be forgotten. Augmented reality technology has the potential to reduce this time wasted by projecting digital content directly into the user's field of view as well as allows the user to document their work while completing their tasks.

Another issue with using laptops is that they cannot provide the level of communication engineers need in order to optimize their conversations with other experts. Traditionally engineers use cell phones, a second mobile computer, in order to communicate with others. This commonly requires the engineers to vocally describe the issue at hand which can lead to confusion among employees due to poor cell phone connection, inconsistent terminology or lack of availability. With AR technology, the on-site technician could use the camera on their head-mounted device to transmit a real-time video of exactly what they are looking at back to an expert in a different location. This technology could be used in order to effectively communicate any issues present, in real time, and collaborate on a solution with remote experts who are not actively on site. Furthermore, this technology allows the remote expert to make illustrations directly onto the on-site user’s video feed in order to isolate a part or location that is of particular interest, eliminating any patenting issues surrounding differences in terminology. This thesis hypothesized that this higher level of communication woul lead to faster response times and more effective technician performance.

Engineers need access to a mobile computer without the excessive steps currently required to fulfill this need. Augmented reality technology has the ability to display the same content as a mobile computer but in a format that is projected onto the user's field of view. This combined with the hands-free interaction that a head-mounted display possesses would provide engineers with the computer tools they need while reducing the excessive steps described above.

Existing research has shown at AR technology has proven value in a manufacturing environment (Elia, Gnoni, & Lanzilotto, 2016; Yew, Ong, & Nee, 2016; Uva, 2018; Kim, 2018), however, very little research has been collected on the perceived value that a service engineer had for this technology (Kurkovsky, Koshy, Novak, & Szul, 2012, p. 72). Technology acceptance models, with associated measurement scales, have been developing and expanding since the late 1980s (Davis F. D., 1985; Davis, Bagozzi, & Warshaw, 1989). These scales can be used to measure a user's perceived value and behavioral intentions towards a particular technology. The Technology Acceptance Model (TAM) was first introduced by Fred D. Davis and Richard Bogazzi in 1989 and is the most widely applied model of users' acceptance and usage of technology (Venkatesh, 2000) TAM theorizes that the perceived usefulness and ease of use of a technology system has a large impact on a person's attitude and behavioral intentions towards using that technology in the future (Davis, Bagozzi, & Warshaw, 1989). In the year 2000, Venkatesh and Davis expanded the model to include perceived usefulness and usage intentions in terms of social influence (i.e. subjective norms, voluntariness, image) and cognitive instrumental processes (e.g. job relevance, output quality, result demonstrability) in what is now known as TAM2 (Venkatesh, 2000). In an attempt to consolidate the prominent existing technology acceptance models, Venkatesh, Morris, Davis G. and Davis F. Davis (2003) reviewed eight models to formulate the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT was found to outperform each of the individual models and prove itself to be a

> "useful tool for managers needing to assess the likelihood of success for new technology introductions and helps them understand the drivers of acceptance in order to proactively design intervention (including training, marketing, etc.) targeted at populations of users that may be less inclined to adopt and use new systems." (Venkatesh, Morris, Davis, & Davis, 2003, p. 426)

This thesis used the methods illustrated in UTAUT and UTAUT2 to record service engineers' willingness to use AR technology and purposed a possible method of adoption with the end-user's needs in mind.

1.2 Problem Statement

There is not enough research on the use and acceptance of augmented reality technology, among engineers working in a manufacturing environment, to support AR technology as a viable tool for large scale adoption.

1.3 Research Question

1. Will augmented reality effectively increase performance while completing a task in a maintenance and service environment?
2. Is augmented reality technology accepted as a viable tool for future adoption within a manufacturing environment, based on the key determinants and their moderating variable as described in the extended Unified Theory of Acceptance and Use of Technology?

1.4 Scope

This study was an attempt to further understand how augmented reality could reduce the time required to provide maintenance services. Laptop computers are effective in delivering important information to engineers however, they lack the mobility and durability required to work anywhere and everywhere that an engineer may need to go (King, 2017). Augmented reality technology currently on the market allows the user to view and create PDF files, Word documents, Excel spreadsheets and many other common forms of information using a system that virtually places a mobile screen directly in front of the user. Using a head-mounted display, this hands-free projection and creation of information could eliminate the need to step away from a worksite to locate a computer or mobile device such as a cell phone, laptop, or tablet. AR technology also enables the user to communicate with others through text message, email, phone call or even video chat, hands-free, using "talk to text" voice recognition. Additionally, users can send and receive pictures, audio files or videos in order to better illustrate their point of view. With the assistance of augmented reality, engineers would no longer need to leave their workstation in order to view content from their mobile computer. Instead, with a head-mounted display, content could be projected and removed from their field of view as often as it is needed. This thesis study recorded the use of AR technology in a maintenance and servicing environment to capture any improved productivity the user experienced. This information helped illustrate the value of AR technologies in a maintenance and servicing environment as well as expanded on existing research surrounding the potential positive advantages of adopting AR technology into the workforce.

“For technologies to improve productivity, they must be accepted and used by employees in organizations” (Venkatesh, Morris, Davis, & Davis, 2003, p. 426). This thesis was an attempt to collect the opinions of service engineers who have had exposure to AR technology in order to illustrate a technician’s willingness to accept this new technology. Using the methods outlined in UTAUT/UTAUT2 and the collected responses of engineers, exposed to AR technology, this thesis study attempted to explain any variances in AR technology use, made predictions on the acceptance and adoption of AR technology, and provided suggestions for future AR development.

1.5 Significance

Augmented reality has the potential to take the manufacturing industry to greater heights by delivering content in an innovative and dynamic way that connects both the digital world and the physical world. In a field service environment, one use case reported a 17% reduction in handling time as well as an 18% reduction in rework needed after a service was conducted. (Kim, 2018). Additionally research conducted into the safety benefits of AR usage reports a potential increase in situational awareness and reduction of errors that may be hazardous in a manufacturing environment (Laughlin, 2018). Due to the high up-front cost of acquiring useful hardware and software relative to augmented reality, projected returns on investments tend to be long term, but use cases that prove value quickly could help organizations determine the best areas for adoption (Kim, 2018). Because of this, there is an evident need, among both consumers and developers of AR technology, for research on how this technology will be accepted by the workforce of the future (Fiorentini, Johnson, & Joseph, 2017). One report from Upskill Inc. reported that 85% of the technicians who used their platform stated that they “believe using this system will reduce manufacturing errors” and that the mechanics “would [use] this even when nobody else is in order to make [their] job easier” (Kim, 2018). This indicated that, in the appropriate environment, acceptance of AR technology is relatively high and beneficial to the users but more research is needed to expand the general knowledge around the adoption of AR tools.

This thesis was an extension of past research in the adaptation of augmented reality to promote more efficient work environments. Primarily this thesis measured and recorded the acceptance and use of augmented reality in a manufacturing environment but this thesis also promoted the use of AR technology overall. Specifically, this project advanced the use of augmented reality to improve computer access within the maintenance and servicing of advanced manufactured products. Finally, this thesis promoted the use of head mounted display devices and provided recommendations on how to further incorporate augmented reality into future manufacturing environments.

1.6 Definitions

Augmented Reality – A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view (Elia, Gnoni, & Lanzilotto, 2016).

Head-Mounted Display – A display device, worn on the head or as part of a helmet, that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD) (Elia, Gnoni, & Lanzilotto, 2016).

Haptic Force Feedback - A product usually worn on the body or held in the hand that vibrates to communicate some form of information (Elia, Gnoni, & Lanzilotto, 2016).

Perceived Usefulness - The degree to which a person believes that using a particular system would enhance his or her job performance (Davis, Bagozzi, & Warshaw, 1989).

Perceived Ease-of-use - The degree to which a person believes that using a particular system would be free from effort (Davis, Bagozzi, & Warshaw, 1989).

Performance Expectancy - The degree to which an individual believes that using the system will help him or her to attain gains in job performance (Venkatesh, 2012).

Effort Expectancy - The degree of ease associated with the use of the system (Venkatesh, 2012).

Social Influence - The degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh, 2012).

Facilitating Conditions - The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system (Venkatesh, 2012).

Hedonic Motivators - The fun or pleasure derived from using a technology (Venkatesh, 2012).

Price Value - The monetary cost of using the technology (Venkatesh, 2012).

Habit - The extent to which people tend to perform behaviors automatically because of learning (Venkatesh, 2012).

1.7 Assumptions

The assumptions for this project include:

- The research is assuming that all engineers are trained to provide adequate maintenance services.
- The researcher is assuming that the members of this study will answer honestly during surveys, focus groups, or interviews.
- The researcher is assuming that the hardware and software selected for this study is an accurate representation of how the current technology can be applied in a working environment.

1.8 Limitations

The limitations of this project include:

- The researcher must follow all safety regulations while conducting usability testing.
- The researcher is limited to using the tools and toolkits provided by Purdue University.
- This study is limited to a small group of service engineers.
- This study is limited to the 6 HMD devices that are available for distribution.
- This study is limited by the schedules and location of participants.
- Influential factors such as vision problems, safety concerns, or work practices may limit the results if this study.

- This study cannot prevent the participants from completing their work in a timely manner.

1.9 Delimitations

The delimitations for this project include:

- The researcher will be using Qualtrics to collect survey data during this study. No other surveys management software will be used.
- The researcher will be suggesting future test cases with AR technology, the researcher will not be implementing these suggestions.

1.10 Chapter Summary

A technician working in a manufacturing environment relies heavily on computers to deliver instructional content, document their processes, and to communicate with other employees. Currently, engineers use laptop computers and mobile phones to accomplish these tasks. In order to access these devices, engineers are commonly required to stop what they are doing and leave their workstation. This increases the time it takes to finish a task as well as increases the chances of a mistake happening or forgetting the information that is not readily available. Using AR technology, engineers can project digital content directly into their field of view; virtually eliminating the need to leave their workstations. Prior research has shown that using AR technology in a manufacturing environment lowered the time required to complete a task and virtually eliminated the chances of missing a step or making a mistake (Elia, Gnoni, & Lanzilotto, 2016; Yew, Ong, & Nee, 2016; Uva, 2018; Kim, 2018) Although research has proven AR's value as a tool for manufacturing, very little research has collected the end user's perceived value of the tool. This thesis was an extension of past research in the adoption and acceptance of augmented reality to promote the use of head-mounted displays in a manufacturing environment.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

There is a unique form of technology working its way into the workforce and it is providing modern opportunities for people seeking to bridge the gap between the physical world and the digital world. Augmented reality (AR) is a technology that allows for the viewing of holograms, or graphic images, that in turn interact with the physical world around the user. This technology has the potential to change the way employees interact and work to achieve a common goal.

This thesis investigated the impact that AR technology can have on engineers working to provide maintenance and service support to advance manufactured products. A pilot study, conducted at an advanced diesel manufacturing facility in Utah, followed a group of engineers as they performed diagnostic and maintenance services on a vehicle that was not performing as it should. Prior research and personal conversations with the employees at this location both confirm that there is an evident need among engineers for a quick and effective way to access and view important documents related to the services they are attempting to perform (Kurkovsky, Koshy, Novak, & Szul, 2012; King, 2017) A major disadvantage of the current method used to accomplish this task is that the engineer must leave their work environment in order to locate and view these documents. The time expended to perform these actions has the potential to distract the engineer or break their train of thought, limiting their ability to perform the requested maintenance. (Laughlin, 2018) According to J. King (2017), engineers have expressed a need to communicate with each other in a more effective way. More specifically, engineers desire the ability to share their point of view with other members of their team, so that an expert in a separate, remote, location can see what the on-site engineers are seeing and provide the most informed assistance. In the first few sections of this literature review, this thesis examined how AR technology is being applied as a tool for research, discussed the practicality of mobile augmented reality, and analyzed how AR technology is making an impact within multiple industries.

A major goal of this study was to analyze AR technologies viability for large-scale adoption within an industrial manufacturing environment. In order to better understand AR technology's impact on the industrial workforce, more research is needed on the attitudes and use behavior of employee's who are exposed to AR tools. The later sections of this literature review provided background information surrounding the formation and extension of the Unified Theory of Acceptance and Use of Technology. (Venkatesh, 2012) Last this literature review defined each of the key constructs that act as determinants of user acceptance and behavior (e.g. performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit) and specified the role of key moderators (e.g. gender, age, and experience) for each construct.

2.2 Introduction to Augmented Reality

Augmented reality is a concept of mixed reality, and "describes systems that combine virtual and real-world elements in order to create new visualized environments capable of real-time interaction where digital and physical objects co-exist" (Kurkovsky, Koshy, Novak, & Szul, 2012, p. 68). For example, researchers at a university in Spain developed an application that supports audience communication during a presentation. This application allowed someone who was presenting in front of a group to, anonymously, view the individual comprehension levels of each person in the room. The audience members were able to use a cell phone or tablet device to select one of three categories that describe their level of understanding. There was one category for those who understand the material; this group was represented by a green check mark. Another group was for those who do not understand the material at all which was represented by a red "x" symbol and the last group was for those who were somewhere in the middle and were represented by a yellow question mark. The individual presenting in front of the group wore a set of AR goggles so that when they looked out at the audience they could see the appropriate, colored symbol hovering above each audience member's head as well as a pie chart showing percentages for each comprehension group in the room. By utilizing AR technologies, the application was able to "assist the speaker in adapting the content and pace of the explanation to the listener(s) but also helped to better manage and improve the flow of the presentation" (Zarraonandia, Aedo, Diaz, & Montes, 2014, p. 837). Other AR tools have been developed which can take tourists on a self-guided, holographic, tour of a city while providing them with additional information about surrounding building without the need of a tour guide (Hwang, Chu, Lin, & Tsai, 2011; Chang & Liu, 2013; Chou & Chanlin, 2014). Another AR application was able teach engineering students about radio signals by using a holographic colored bubble to represent a Wi-Fi signal's range in a room (Sahin, et al., 2016). AR technology has also being used to deliver instructions to construction workers and engineers working in a manufacturing environment (Elia, Gnoni, & Lanzilotto, 2016; Yew, Ong, & Nee, 2016; Uva, 2018). In these examples, employees were able to use AR to guide them through step by step instructions (Webel, et al., 2013; Kim, 2018), for the training of new employees (Webel, et al., 2013), to virtually use machines from a separate remote location (Elia, Gnoni, & Lanzilotto, 2016), or to connect with a remote expert and gain assistance from someone who was not actively on-site with them (Wang & Brenner, 2012; Webel, et al., 2013; Kim, 2018). These examples illustrated positive applications of AR technology in our field of interest and supported the need for this research.

With that being said, clear and obvious limitations to the practical use of the AR systems arose in the ergonomic constraints of the AR hardware. The goggles worn by the presenter in the first example were tethered to a string of cables that had to be managed while using the device, which limited a user's movement during presentations. In addition, the goggles used were rather bulky and deemed "too unwieldy to be used in a real presentation" (Zarraonandia, Aedo, Diaz, & Montes, 2014, p. 834). Mobile augmented reality is needed to expand the use of AR technologies and mitigate the limitation of a static AR system. The next section of this literature review further explained the importance of mobile AR and the developments in AR technology that have made it a viable tool for adoption within future industries.

2.3 Mobile Augmented Reality

Mobile augmented reality is only possible "if the hardware required to implement an AR application is something that you take with you wherever you go" (Craig, 2013, p. 209). Common tools for mobile augmented reality are cell phones or tablets because these devices are lightweight, they can be operated while walking, and they can easily be taken to a different location whenever and wherever. Although people are commonly more familiar with cell phones or tablets, many disadvantages with handheld augmented reality make it less desirable for AR applications. For example, in their article Kurkovsky, Koshy, Novak, and Szul (2012) say that:

> Using AR applications on smartphones equipped with a camera on the opposite side of the display encourages the use of the 'magic lens' metaphor describing the fact that the users

> have to point and look ‘through' the device to view the augmented representation of the real world. This metaphor imposes a number of ergonomic constraints on the design of handheld AR applications. For example, the device must be held at a certain distance with the camera aimed in the direction of the real-world scene to be augmented… The field of view is limited by the size and resolution of the smartphone's screen and camera's optical characteristics. [Furthermore] although it is relatively easy to steadily move the device while standing, it is much more difficult to do so while walking which would have a negative impact on the perceived quality of the AR imagery displayed on the screen” (p. 68).

Another form of mobile augmented reality is a head-mounted display. This device is worn on the head, in front of the eyes, in order to project images into the user’s field of view. Organizations like Microsoft, Magic Leap, ODG, Seiko Epson Corporation, and RealWear are working to develop new and innovative, head mounted, solutions as they discover new problems and demands that surround augmented reality in conjunction with the enterprise of the future. One particularly difficult hurdle for companies that currently develop AR smart glasses technology is creating a product that will have the computational power of a holographic computer but remain comfortable enough to wear for long periods of time. Up until recently, "many head-mounted displays [were] mobile in nature but [were] still rather cumbersome, and most people [could] not wear them on a daily basis" (Craig, 2013, p. 210). Newer products such as the ODG R8 or RealWear HMT-1 are showing improvements in weight, battery life, and field of view that suggest mobile augmented reality and HMD devices will be highly advantageous for engineers providing maintenance services in the future. If AR technology is to be effectively fully integrate into current work practices it must seamlessly connect the physical world with the digital world without introducing constraints around mobility or safety. Unlike cell phones or tables, HMD devices are able to assist the user in a hands-free format that is much safer for the user.

2.4 AR in Enterprise

Researchers from the Department of Innovation Engineering at the University of Salento proposed a method to rank and select different types of AR devices, depending on the given task. The first thing they did was categorize augmented reality devices into groups. These groups were head-mounted displays, handheld devices, projectors, and haptic force feedback devices. For this study, haptic force feedback devices describe a product usually worn on the body or held in the hand that vibrates to communicate some form of information. The research team was able to evaluate each AR device category based on three criteria: reliability, responsiveness, and agility. The team then tested their methods in a case study where they attempted to select the best AR device for "maintenance tasks at a manufacturing firm producing high technological equipment for railway infrastructures" (Elia, Gnoni, & Lanzilotto, 2016, p. 192). The results of this study showed that each device had strengths for different tasks, but the most effective category of AR devices for the analyzed goal were handheld devices. Results highlighted that handheld devices were the most reliable system and therefore best AR device, but this was specific to the test case. Overall, HMD devices and projectors outperformed tablets in the responsiveness and agility criteria. In addition, HMD devices were also found to perform best in the task of providing data specifically during the completion of a task. Despite the fact that our research is different from the study outlined in their article, the information provided by Elia, Gnoni, and Lanzilotto (2016) was very useful for supporting an effective feasibility assessment about AR technologies in regards to our case study. This study proposed that head mounted display devices are the best selection for assisting maintenance engineers who need to consume information, hands-free, while they perform tasks.

Many advanced manufacturers are already looking to adopt AR technology into the work they conduct. The Augmented Reality for Enterprise Alliance (AREA) is currently “the only global non-profit, member-based organization dedicated to the widespread adoption of interoperable AR-enabled enterprise systems” (AREA, 2018). In 2017 AREA partnered up with the Digital Manufacturing and Design Innovation Institute (DMDII) to bring together both producers and consumers of AR technology to discuss and collaborate existing concerns and issues surrounding AR technology. Organizations that attended these workshops in 2017 and 2018 included Accenture, Boeing, Caterpillar, NVIDIA, Lockheed Martin, Microsoft, Procter and Gamble, PTC, ScopeAR, Upskill and the U.S. Military and all of these organizations intended to incorporate AR technology into their future manufacturing processes (AREA, 2018).

Currently, AR technology’s two main uses within a manufacturing environment, as illustrated during these workshops, are for the delivery of instructional content and the use of real-time video conferencing in order to assist an employee with a work task. The concept of "see what I see" communication describes a phenomenon where a user would be able to display their point of view by recording or streaming a video that is captured using a front-facing camera. This allows others to see what the user is experiencing at that exact moment so that they may provide the appropriate feedback, in real-time. This is a new level of communication that is currently being heavily researched by manufacturing companies and investors have expressed a serious desire to see it come to market. Similar to the issue with hands-free communication, if a technician wisheds to consult a maintenance document they must first clean themselves up and then leave their workstation to locate and view this document. The advantages of having these documents readily available to engineers in their digital form are inexhaustible within the manufacturing industry. Imagine the time that would be saved if a user could pull up a database full of important documents right into their field of view, then quickly search and select the document that they need, all without moving away from the product they are working on. This is exactly what researchers developing for enterprise hope to produce in the future.

In 2017 most of the AR workshop focused on discussing the consumers' functionality needs, in reference to AR technology, on both the hardware and software levels. During this discussion, a large emphasis was given to outlining the hardware requirements for industrial application with major concerns surrounding battery life, mobile constraints, and field of view. The following year's discussion of AR application focused on the growing safety and security concerns associated with adopting AR systems into the workforce. Additionally, some discussion was held on the “cultural acceptance” of AR technology, discussing employee’s willingness to use the devices. This thesis hoped to expand and shed some light on the “cultural acceptance” of service engineers in a manufacturing environment.

Although there are numerous case studies that explored the potential value of augmented reality’s functional abilities, there is no evidence of a full-scale AR application that has been completely integrated into a company or, in other words an application that changes the company’s practices and policies (Elia, Gnoni, & Lanzilotto, 2016). Kurkovsky, Koshy, Novak and Szul (2012) proposed a possible explanation for this in saying:

> “The issues of usability seem to be the least explored in the current body of work, possibly because it is imperative to first achieve a functional technological AR solution, which then can be made more practical by studying the usage patterns, user preferences and interaction modalities” (p. 72).

Evidence of technology advancements and low scale adoption suggests that the functional capabilities of AR solutions have advanced past this area of research to a point where determinants of usability and acceptance need more exploration. The rest of the literature review examined the development of technology acceptance testing and outline the theorized determinants of user behavior.

2.5 Technology Acceptance Testing

The goal of the Technology Acceptance Model (TAM) is “to develop and test a theoretical model of the effect of system characteristics on user acceptance of computer-based information systems” (Davis F. D., 1985, p. 7). This model was founded on the Theory of Reasoned Action (TRA) purposed by Martin Fishbein and Icek Ajzen in 1967 (Davis F. D., 1985, p. 17). The TRA is defined using three equations to calculate what Fishbein theorizes are the main causal determinants of a person’s behavior. Those determinants are: a person’s intention to perform a given behavior, a person’s attitude towards a given behavior, and a person’s subjective norm or “the perceived expectations of specific referent individuals or groups and the person’s motivation to comply with those expectations” (Fishbein & Ajzen, 1975, p. 302), The Technology Acceptance Model uses the TRA an “appropriate theoretical paradigm in view of the research objectives” (Davis F. D., 1985, p. 15), but focuses on the attitudes of a person and adjusts Fishbein’s model to analyze technology acceptance as the behavior. In order to quantifiably illustrate a user's acceptance towards technology, Davis developed two separate scales to measure a user's perceived usefulness and perceived ease of use. The measurement item used to develop these scales took the form of survey questions and were "derived from published articles that have discussed or attempted to measure the target constructs" (Davis F. D., 1985, p. 80). Generating items in this way introduces two advantages.

> "First, there is a rich set of existing articles available to draw from, many of which have themselves employed a variety of qualitative elicitation as well as quantitative analysis techniques to understand how subjects think about these constructs. Second, these existing articles cut across a wide range of target systems, user populations, and usage environments." (p. 81)

Although there are alternative models for the measurement of technology acceptance Davis’s TAM has become the preferred choice among behavioral researchers. Several studies have replicated Davis’s process in order to test the robustness and validity of the questionnaire used in Davis’s original study. Adams, Nelson, and Todd found that “the ease-of-use and usefulness scales developed by Davis fared well in [their] replication” and that “these results provide further evidence of the validity of the two scales” (Adams, Nelson, & Todd, 1992, p. 239). When replicated by Hendrickson, Massey, and Cronan, they found Davis's questions had high reliability and good test-retest reliability (Chuttur, 2009, p. 11). Davis has continued to expand his research, upgrading the original TAM into a model known as TAM 2 as well as developing the Unified Theory of Acceptance and Use of Technology. The next section of this thesis covered this last model more in-depth as it is the most recent expansion of the Davis's TAM and provides the best analysis of technology acceptance behavior.

2.6 Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) is a technology acceptance model formulated by Venkatesh and others in 2003, through the review and consolidation of past information technology acceptance research. This theory expands on past user acceptance research including the TRA and TAM. It is designed to explain user intentions to use an information system based on four key constructs (e.g. performance expectancy, effort expectancy, social influence and facilitating conditions) and four moderators (e.g. age, gender, experience, and voluntariness) (Venkatesh, Morris, Davis, & Davis, 2003). " In longitudinal field studies of employee's acceptance of technology, UTAUT explained 77 percent of the variance in behavioral intention to use a technology and 52 percent of the variance in technology use" (Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, Thong, & Xu, 2016). "Since its original publication, UTAUT has served as a baseline model and has been applied to the study of a variety of technologies in both organizational and non-organizational settings" (Venkatesh, 2012). In 2012 UTAUT was expanded into UTAUT2 by identifying hedonic motivation, price, and habit as additional key constructs to be integrated into UTAUT. Other changes relative to the original UTAUT include removing "voluntariness" as a moderator and adding a link of influence between facilitating conditions and behavioral intention. Figure 2.1 shows the original UTAUT model in lighter lines and the expanded UTAUT2 model represented in darker lines (Venkatesh, 2012, p. 160).

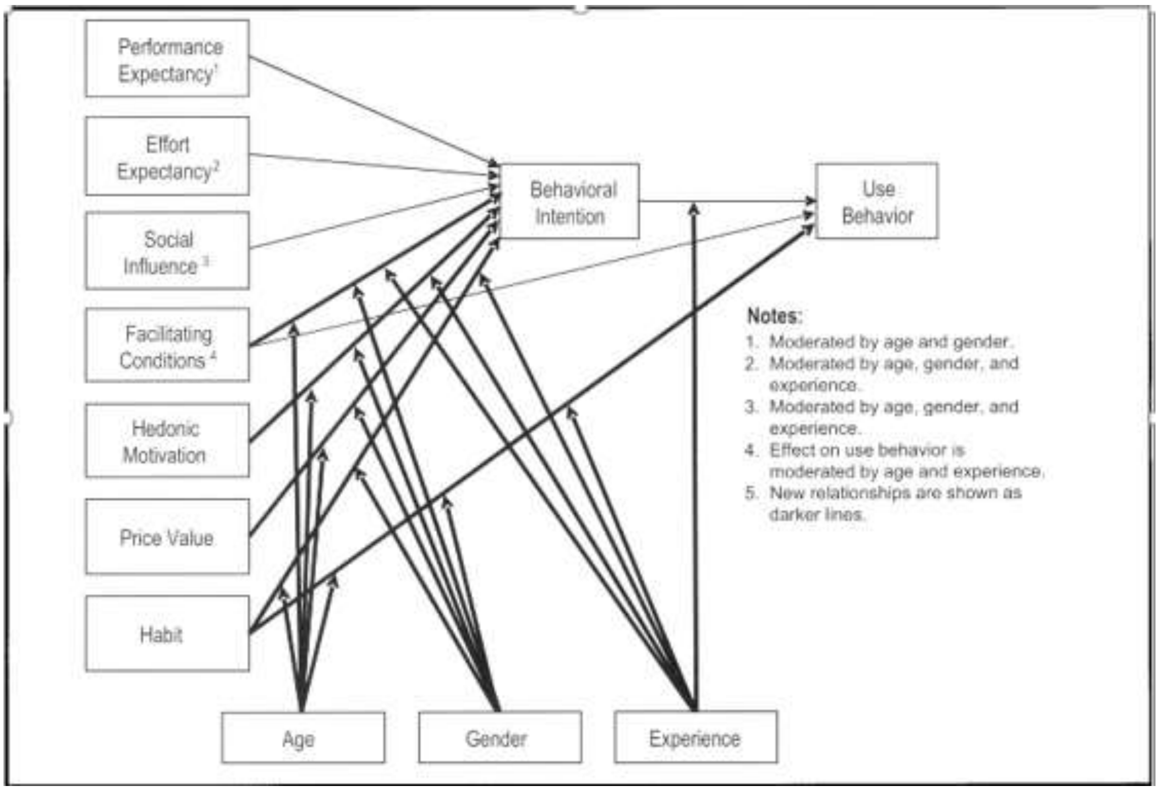

Figure 2.1 UTAUT2 Research Model (Venkatesh, 2012)

2.7 Key Constructs and Moderators

Performance expectancy is the first key construct introduced by Venkatesh et al. in the original UTAUT. Performance expectancy is defined as the degree to which an individual believes that using the system will help him or her to attain gains in job performance. In previous model tests performance expectancy is consistently the "strongest predictor of intention and remains significant at all points of measurement in both voluntary and mandatory settings" (Venkatesh, Morris, Davis, & Davis, 2003, p. 447).

> Research on gender differences indicates that men tend to be highly task-oriented (Minton & Schneider 1980) and, therefore, performance expectancies, which focus on task accomplishment, are likely to be especially salient to men… Similar to gender, age is theorized to play a moderating role. Research on job-related attitudes (e.g., Hall & Mansfield 1975; Porter 1963) suggests that younger workers may place more importance on extrinsic rewards. Gender and age differences have been shown to exist in technology adoption contexts also (Morris & Venkatesh 2000). In looking at gender and age effects, it is interesting to note that Levy (1988) suggests that studies of gender differences can be misleading without reference to age. For example, given traditional societal gender roles, the importance of job-related factors may change significantly (e.g., become supplanted by family-oriented responsibilities) for working women between the time that they enter

> the labor force and the time they reach child-rearing years (e.g., Barnett and Marshall 1991) (Venkatesh, Morris, Davis, & Davis, 2003, p. 449).

Thus performance expectancy is expected to be moderated by both gender and age in this study.

The next construct identified in the original UTAUT is effort expectancy and is defined as the degree of ease associated with the use of the system. Effort-oriented constructs are expected to be more salient in the early stages of a new behavior when process issues are higher and users work to pass the initial learning curve. As time progresses, however, users become more familiar with the technology and previous research has shown that effort expectancy becomes non-significant after “periods of extended and sustained usage” (Davis, Bagozzi, & Warshaw, 1989). Effort expectancy is expected to be influenced by all of the moderators, gender, age, and experience. "Prior research supports the notion that constructs related to effort expectancy will be stronger determinants of individuals' intention for women and for older workers" (Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, 2000).

Social Influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system. This construct encompasses the notion that “an individual's behavior is influenced by the way in which they believe others will view them as a result of having used the technology” (Venkatesh, Morris, Davis, & Davis, 2003, p. 455). Much like effort expectancy social influence appears to be most significant during the initial stages of acceptance testing. Social influence is unique however because it appears to only become significant in situations where a behavior is mandatory (Venkatesh, Morris, Davis, & Davis, 2003, p. 455; Venkatesh, 2000). Social Influence also has a complicated interaction of moderators. Theory suggests that women find social influence more salient yet the effects of social influence become less salient regardless of gender as experience increases. Age works similarly with social influence growing in salience as age increases but again will decrease as experience grows. With all three moderators simultaneously influencing each other as well as influencing the social influence construct this is the most complex of the key determinants listed in UTAUT and its extended works.

Facilitating conditions are the last of the original constructs introduced in the original UTAUT. Facilitating conditions are defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system. In the year 2000, Venkatesh made attempts to prove that measuring the effects of effort expectancy mediates the need measure the effects of facilitating conditions, but empirical evidence indicated that "facilitating conditions do have a direct influence on usage beyond that explained by behavioral intentions alone" and these effects increase as experience grows and users find more outlets to gather the assistance they need. Facilitating conditions are expected to be moderated by age and experience and if done so effectively has the potential to significantly influence over user intentions (Venkatesh, 2012, p. 162).

This first construct introduced in the most recent expansion of UTAUT, also known as UTAUT2, is hedonic motivation. Hedonic motivation is defined as the fun or pleasure derived from using a technology. Hedonic motivation is derived from three associated elements: innovativeness, novelty seeking, and perceptions of the novelty of a target technology. UTAUT2 defines innovativeness as "the degree to which an individual is receptive to new ideas and makes innovation decisions independently" (Venkatesh, 2012, p. 161). Novelty seeking is used to describe a tendency of an individual to seek out novel information or stimuli and perceived novelty of a target technology is the value a user places on that novel information or stimuli. "When a consumer begins to use a particular technology, they will pay more attention to its novelty… and may even use it for the novelty" (Venkatesh, 2012, p. 163). Hedonic motivation is expected to be moderated by age, gender, and experience. Based on the results of UTAUT2 we can expect that as experience and age increase hedonic motivation will have less of an effect on the user's acceptance and use of a technology. In past research hedonic motivation has been shown to be a strong determinant of technology acceptance and use and in turn a strong predictor of consumer's behavioral intention to use a technology (Venkatesh, 2012, p. 163).

The next construct introduced by UTAUT2 is price value or the monetary cost of using the technology. This construct did not come to play in the first iteration of UTAUT because development of the original UTAUT took place in an organizational setting where the actual user did not have to consider the cost of using the technology. However, as UTAUT evolved to accommodate a consumer based setting, price value was added as a key construct that determines a user's acceptance and use of a technology. Price value has a positive effect on behavioral intentions when the benefits of using a technology are perceived to be greater than the monetary cost and an inverse effect when the benefits are perceived to be lower. Price value is expected to be moderated by age and gender however these expectations are based strictly on theories about social roles (Venkatesh, 2012, p. 160).

The final construct introduced in UTAUT2 is a habit which is defined as the extent to which people tend to perform behaviors automatically because of learning. Habit is purposed as an extension of the experience moderator developing from the results of prior use of a technology. Habit is unique in that, through the passage of time, experience can still be gained even if a habit is never formed. Additionally, habit formation can have a positive effect on the acceptance and use of a technology while the absence of a habit may or may not have a negative effect on acceptance and use of a technology. Prior psychological studies conducted by Kim and Malhotra (2005), Ajzen and Fishbein (2005), and Limayem, Hirt, and Cheung (2007) are all referenced in Venkatesh's UTAUT2 and support the claim that prior use is a strong predictor of future technology use. Venkatesh operationalizes experience as the passage of time from the initial use of a target technology and operationalizes habit in keeping with Limayem et al. (2007) as a self-reported perception (Venkatesh, 2012, p. 164). Habit is expected to be moderated by age, gender, and experience. Experience is expected to have the greatest effect on habit in the sense that habit will have a stronger effect on intention and use for more experienced users. Age and gender moderators "reflect people's differences in information processing… that in turn can affect their reliance on habit to guide behavior" (Venkatesh, 2012, p. 159).

Outside of these key determinants, behavioral intention is also expected to be moderated by experience. With increasing experience, routine behavior becomes automatic and is guided more by the associated cues (Venkatesh, 2012, p. 166). Venkatesh suggests that as experience grows users are able to find solutions without the assistance of technology effectively lowering their need to use technology.

2.8 Chapter Summary

In conclusion, there is a definite need to adopt augmented reality within the manufacturing industry. Engineers need the information necessary to complete a task and they need it immediately. Without this information, common tasks take longer to complete and mistakes can easily be made in the process. The use of augmented reality helps to mitigate these issues and improve the efficiency of employees. For AR technology to perform at its highest potential the device must be hands-free and mobile. There are numerous case studies and evidential research that suggest AR technology is applicable in a manufacturing setting, however, there is still a definite need for further research on the acceptance and use of augmented reality. This is reflected by the fact that industries have not yet accepted a permanent application for augmented reality.

Models designed to measure the acceptance and use of technology have been under development since the late 1980s. These models have been criticized, expanded and unified into one model known as UTAUT. This theory provided a foundational baseline for this thesis which can be adjusted to measure and analyze the acceptance and use of AR technology in a manufacturing environment.

CHAPTER 3. METHODOLOGY

The Purdue University's Product Lifecycle Management Center of Excellence is frequently contacted by organizations for research projects specifically geared towards that individual company. Purdue University worked in partnership with an organization, specializing in the manufacturing of advanced diesel engines, to adopt augmented reality technology into their workforce. Although this research was in the initial pilot study stages, it provided a strong opportunity for this study to collect the usability data needed to measure each user's acceptance of this new technology in a professional manufacturing environment. In order to accomplish this task, this study distributed a questionnaire, at regular intervals of 5 weeks, to collect the user's level of use and acceptance while the engineers were introduced to the new technology.

3.1 Participants

Participants in this study were all trained service engineers working for the advance diesel manufacturer mentioned earlier. These diesel engineers were experienced in electrical engine systems, the anatomy of engine construction, and diagnostic maintenance for personal and professional use. Participants routinely performed corrective maintenance on a myriad of trucks, buses, construction equipment and farming equipment specific to this organization. Participants were selected using a convenience sampling method based on social influence, availability and exposure to innovative technology (Moore, McCabe, & Craig, 2009). There were 13 individual participants in this study, however in certain instances inconsistent data had to be removed. Those instances are further explained in the results portion of this thesis. Due to the small size of this test population this study was not representative of all engineers in a manufacturing environment but this study could be used to make assumptions towards the behavior of other service engineers working in the United States (Moore, McCabe, & Craig, 2009). All participants were individually surveyed and their responses were kept confidential. Because names were not recorded during this study, in order to maintain participant anonymity, each participant was assigned a user ID. The age, gender, and years of experience reported at the beginning of each survey were used to confirm that the user ID aligned with each round of responses. Table 3.1 shows a complied list of each participant and their defining attributes. This study was completely voluntary, use of the AR platform was not mandatory, and all participants were able to withdraw from the study at any time for any reason.

Table 3.1 Description of Participants

USER ID	AGE	GENDER	YEARS OF EXPERIENCE
1	46	Male	19
2	47	Male	13
3	23	Male	2
4	23	Female	0.5
5	54	Male	23
6	33	Male	8
7	37	Male	12
8	52	Female	25
9	35	Male	12.5
10	40	Male	13
11	42	Male	21
12	26	Female	3.5
13	22	Male	1

3.2 Materials/Apparatus

For this study, participants received a, self-complied, “HMT-1 Initial User’s Guide” and “Remote Expert Guide” (APPENDIX B) in order to train them on how to use the AR platform. A self-compiled survey was created, using the methods and questions illustrated in UTAUT and UTAUT2, and distributed online using the Qualtrics research software. . These questions are provided in table 3.2. The survey consisted of 32 items validated in prior research (Venkatesh, 2012, p. 166) and adapted to the technologies and organizations in this study. A Seven-point Likert scale was used for all construct measurements (e.g. performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, habit, and behavioral intentions), with a value of -3 at the negative end of the scale and a value of +3 at the positive end of the scale (Appendix A). Values were coded in this way to center the responses on a value of 0. With this system, acceptance of the technology could be represented with positive values. The questionnaire was revised for terminology and content validity by a group of university staff as well as a team of manufacturing representatives.

Table 3.2 List of Survey Questions

ID	QUESTION
AGE	What is your age?
GENDER	Gender
EXPERIENCE	In years, how long have you worked in a manufacturing environment?
PE1	I find augmented reality technology useful in my daily life.
PE2	Using augmented reality technology increases my chances of achieving things that are important to me.
PE3	Using augmented reality technology helps me accomplish things more quickly.
PE4	Using augmented reality increases my productivity.
EE1	Learning how to use augmented reality technology is easy for me.
EE2	My interaction with augmented reality technology is clear and understandable.
EE3	I find augmented reality technology easy to use.
EE4	It is easy for me to become skillful at using augmented reality.
SI1	People who are important to me think that I should use augmented reality.
SI2	People who influence my behavior think that I should use augmented reality technology.
SI3	People whose opinions that I value prefer that I use augmented reality technology.
FC1	I have the resources necessary to use augmented reality technology.
FC2	I have the knowledge necessary to use augmented reality technology.
FC3	Augmented Reality technology is compatible with other technologies I use.
FC4	I can get help from others when I have difficulties using augmented reality.
HM1	Using augmented reality technology is fun.
HM2	Using augmented reality technology is enjoyable.
HM3	Using augmented reality technology is very entertaining.
PV1	At $2,000 per headset augmented reality technology is reasonably priced.
PV2	Augmented reality technology is a good value for the money.
HT1	The use of augmented reality technology has become a habit for me.
HT2	I am addicted to using augmented reality technology.
HT3	I must use augmented reality technology
HT4	Using augmented reality technology has become natural to me.
BI1	I intend to continue using augmented reality technology in the future.
BI2	I will always try to use augmented reality technology in my daily life.
BI3	I plan to continue to use augmented reality technology frequently.
U1	How frequently do you use augmented reality for real-time conferencing?
U2	How frequently do you use augmented reality for the delivery of instructions?
U3	How frequently do you use augmented reality for note taking?
U4	How frequently do you use augmented reality to browse websites?
U5	How frequently do you use augmented reality for other purposes?

The Atheer AiR Enterprise software package was selected as a strong representation of AR software currently available for purchase. This software had the functionality and customization needed for this study. The ability to conduct real-time video conferences which allowed the user to share their point of view was the function of highest concern. There were more expensive products available that may have performed better in the workplace, however, the high cost of adopting these products removed them as viable products for large-scale adoption. The HMD selected for this study was the Real-Wear HMT-1 head mounted display. This device is a monocular display that provided all the components and functionality needed to integrate an AR device into a manufacturing environment. This device had the most advanced voiced recognition software on the market and the ability to recognize five different languages; a function that made it viable for future adoption in other countries. This device provided an accurate generalization of the hardware currently available in today's market. A more detailed illustration of the hardware is provided in Figure 3.1.

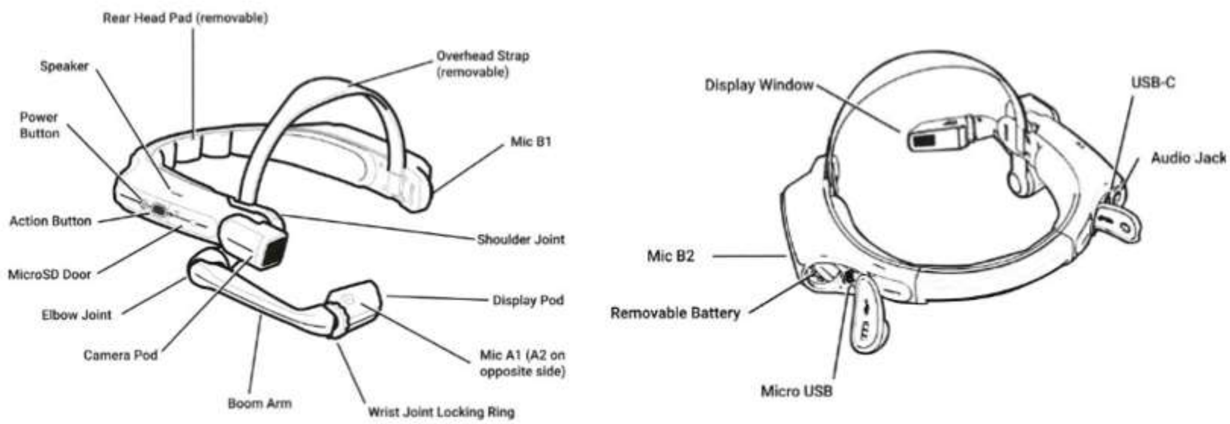

Figure 3.1 HMT-1 Hardware (RealWear, Inc., 2017)

3.3 Data Analysis

Surveys were distributed in three separate rounds. Round 1 (R1) of surveys were collected before the engineers were exposed to the augmented reality technology; 0 weeks of exposure. These responses were used as a baseline reading for the perceived value of the technology and interpreted as the value that the engineers expected to gain from using AR technology. Round 2 (R2) of the surveys were collected after 5 weeks of exposure to the AR technology and round 3 (R3) of the surveys were collected after 10 weeks of exposure to the AR technology.

Using the baseline reading and subsequent rounds of surveys, this study was able to compare survey responses and measure any increases or decreases in the perceived value of the technology. After collecting the responses from each round of surveys a t-test analysis with a 95% confidence interval was performed to determine if there were any changes in perceived value and use of the technology between the individual survey periods. Traditionally a t-test analysis is used to measure the mean difference between two groups; a control group and a treatment group (Moore, McCabe, & Craig, 2009). Due to the nature of this study and the small size of the test population, having a separate control group was not a feasible option. However, this study was able to take values from the same participants at different time intervals and treat them as different groups in order to analyze any significant changes that occurred over time. The t-test analyses compared responses for three testing periods. These period are from round 1 to round 2 or 0 weeks to 5 weeks of exposure to AR technology, from round 2 to round 3 or 5 weeks to 10 weeks of exposure, as well as from round 1 to round 3 or 0 weeks to 10 weeks of exposure. Due to the small size of the test group, bootstrapping methods, with sample replacement techniques, where used to improve the accuracy of the results and provide more significant data (Moore, McCabe, & Craig, 2009, p. 368). Hypotheses on the significant changes for each construct of acceptance are listed below.

H1. There will be a significant increase in values reported for performance expectancy (PE) after exposure to the AR technology.

H2. There will be a significant increase in values reported for effort expectancy (EE) after exposure to the AR technology.

H3. There will be a significant increase in values reported for social influence (SI) after exposure to the AR technology.

H4. There will be a significant increase in values reported for facilitating conditions (FC) after exposure to the AR technology.

H5. There will be a significant decrease in values reported for hedonic motivators (HM) as users become accustomed to using the AR technology over time.

H6. There will be a significant increase in values reported for price value (PV) after exposure to the AR technology.

H7. There will be a significant increase in values reported for habit (HT) after exposure to the AR technology.

H8. There will be significant increase in behavioral intentions (BI) and use (U) of the AR technology indicating an acceptance of the technology.

A correlation analysis was conducted to test for relationships between key determinants and their associated moderators as described in existing UTAUT research (Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, 2012) to support the existing theories on the effects of moderators on key determinants. Additionally a correlation analysis was conducted to look at the relationships between each key determinant and behavioral intentions in order to analyze which determinants motivated the engineers to use the AR platform. This information was used to better illustrate the effects of key moderators on behavioral intentions. Additional hypotheses from existing UTAUT research on the relationships between key constructs and their moderators are listed below.

H9. The effect of performance expectancy (PE) on behavioral intentions (BI) will be moderated by age and gender such that it will have a greater effect on younger males.

H10. The effect of effort expectancy (EE) on behavioral intentions (BI) will be moderated by age, gender, and experience such that it will have a greater effect on females, particularly younger females, but will decrease as experience grows.

H11. The effect of social influence (SI) on behavioral intentions (BI) will be moderated age, gender, and experience such that it will have a greater effect on older females but will decrease as experience grows.

H12. The effect of facilitating conditions (FC) on behavioral intentions (BI) will be moderated by age, gender and experience such that it will have a greater effect on older females with more experience.

H13. The effect of hedonic motivation (HM) on behavioral intentions (BI) will be moderated by age, gender, and experience such that it will have a greater effect on older males but will decrease as experience grows.

H14. The effect of price value (PV) on behavioral intentions (BI) will be moderated by age and gender such that it will have a greater effect on females, particularly older females.

H15. The effect of habit (HT) on behavioral intentions (BI) will be moderated by age, gender, and experience such that it will have a greater effect on older males with high levels of experience.

H16. The effect of behavioral intentions (BI) on use (U) will be moderated by experience such that it will have a greater effect on users with less experience.

CHAPTER 4. RESULTS

The results chapter of this thesis showed the responses for the performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivators (HM), price value (PV), habit (H), behavioral intentions (BI), and use (U) reported by the engineers. An average difference in values is provided to easily compare responses between each round of surveys. Additionally, a t-test analysis was run for each testing period to determine if changes in responses were significant in order to support or reject hypotheses H1 - H8 of this study, for each testing period (Moore, McCabe, & Craig, 2009). This data illustrated any significant changes in the participants' perceived value towards the AR technology. After reviewing the t-test analyses, a correlation analysis was reviewed to describe any evident relationships between key determinants of acceptance and their predicted moderators, described in chapter 2 of this thesis in order to support or reject hypotheses H9 - H16. Finally, a correlation analysis of key determinants and behavioral intentions was reviewed in order to illustrate which constructs of acceptance motivate the engineers' intentions to use the AR technology in the future.

4.1 Round 1 vs Round 2

Analyzing the differences in reported perceived value based on key determinants between round 1 of surveys and round 2 of surveys illustrated the engineer's initial impression of this AR platform after their first five weeks of experience working with this innovative technology. Table 4.1 showed the average response and average difference in responses for each survey item, calculated by averaging the responses and average differences from each associated survey question. 12 out of 13 participants completed a survey for the first round of testing, but only 10 participates completed a survey for the second round of testing. Average differences were taken from the t-test analysis which only compares the 9 responses of those who completed both round 1 and round 2 of the survey, therefore average responses for each associated question were also calculated using only the responses of those who completed both rounds of surveys. Although there were only 9 pairs of responses for this comparison, this information was still valuable to gain an initial representation of the engineers' opinion towards the AR platform and to reference in future testing periods. All responses were documented, and maintained for use in later comparisons.

Table 4.1 Average Survey Responses Round 1 vs Round 2

	R1 AVERAGE LIKERT VALUE	R2 AVERAGE LIKERT VALUE	AVERAGE DIFFERENCE
PE	0.416667	-0.16667	-0.582222
EE	1.138889	0.527778	-0.611111
SI	-0.333333	-0.14815	0.185185
FC	0.861111	0.805556	-0.185185
HM	0.925926	0.814815	-0.111111
PV	-0.05556	-0.38889	-0.333333
H	-0.833333	-1.75	-0.916667
BI	0.111111	-0.18519	-0.296296
U	-0.33333	-2.17778	-1.844444

The t-values, p-values, and confidence intervals calculated from the t-test analysis of round 1 versus round 2 were shown alongside the recalculated values, after bootstrapping techniques were applied, in table 4.2. These values determined which survey items experienced significant changes away from the expected value in the engineer's first 5 weeks of exposure to this AR platform. With the exception of U3 and U4, all other survey items reported a p-value above 0.05, which is traditionally used to determine significance (Moore, McCabe, & Craig, 2009), and therefore the null hypothesis could not be rejected nor confirmed for these items. This is expected from a test populations that is this small.

Table 4.2 T-test Analysis of Round 1 vs Round 2

	T (N=9)	P-VALUE	LOWER BOUND	UPPER BOUND	T (N=27)	P-VALUE	LOWER BOUND	UPPER BOUND
PE1	-0.885	0.4028	-1.6045	0.7157	-1.5667	0.1308	-0.8701	0.1201
PE2	-1.1547	0.2815	-1.998	0.6647	-0.1131	0.911	-0.692	0.692
PE3	-1.4215	0.193	-2.04	0.484	-2.5595	0.0166	-1.6027	-0.175
PE4	-0.8	0.4468	-1.7256	0.8367	0.8778	0.9307	-0.8302	0.9043
EE1	-1.069	0.3162	-2.1047	0.7714	-4.6669	8.1E-5	-2.134	-0.829
EE2	-0.6325	0.5547	-1.5487	0.8820	-3.3087	0.0027	-1.6813	-0.3928
EE3	-1.3598	0.211	-2.0968	0.5412	-6.2822	1.194E-6	-2.2612	-1.4626
EE4	-1.1547	0.2815	-1.998	0.6647	-5.2915	1.56E-5	-2.1598	-0.9513
SI1	0.8	0.4468	-0.8367	1.7256	3.8435	0.0007	0.5169	1.7053
SI2	0	1	-1.2747	1.2747	1.5387	0.136	-0.1617	1.1247
SI3	0.2294	0.8243	-1.0057	1.228	2.209	0.0362	0.04118	1.144
FC1	-0.1754	0.8651	-1.5718	1.3496	-2.371	0.0254	-1.66	-0.1183
FC2	-0.4781	0.6454	-1.294	0.8496	-3.6056	0.0013	-1.5701	-0.4299
FC3	-0.4781	0.6454	-1.2941	0.8496	-2.9197	0.0071	-1.2622	-0.2192
FC4	0.8165	0.4379	-0.6081	1.2748	-1.1402	0.2646	-0.6228	0.1784
HM1	-0.2169	0.8337	-1.2922	1.07	-0.4581	0.6507	-0.8128	0.5166
HM2	-0.4264	0.6811	-1.424	0.9796	-0.6253	0.5372	-0.9527	0.5083
HM3	0	1	-1.153	1.153	-0.1182	0.9068	-0.6072	0.6813
PV1	-0.92057	0.3842	-1.9472	0.8361	-0.5662	0.5761	-1.2	0.682
PV2	-0.1818	0.8602	-1.5203	1.2981	1.0973	0.2826	-0.4528	1.4898
HT1	-1.4142	0.195	-2.6306	0.6306	-2.0577	0.0498	-1.6288	-0.0009
HT2	-1.644	0.1388	-2.6697	0.4474	-3.1623	0.004	-1.8334	-0.3889
HT3	-1.3055	0.228	-2.1516	0.5961	-1.6543	0.1101	-0.9967	0.1078
HT4	-1.1749	0.2738	-2.3044	0.7488	-1.8415	0.077	-1.4108	0.0775
BI1	0	1	-0.7687	0.7687	-1.8829	0.0709	-0.6972	0.0306
BI2	-0.686	0.5121	-1.9385	1.0496	-0.2431	0.8098	-1.0507	0.8284
BI3	-0.8	0.4468	-1.7256	0.8367	-09799	0.3362	-1.1473	0.4066
U1	-0.9363	0.3765	-3.0781	1.3	-3.323	0.0027	-3.1772	-0.7487
U2	-2.2295	0.0563	-2.9385	0.0496	-4.4849	0.0001	-2.3225	-0.8627
U3	-4.1312	0.0033	-4.1552	-1.1781	-7.605	4.51E-8	-3.1522	-1.8108
U4	-3.2827	0.0111	-4.7291	-0.8264	-6.0893	1.96E-6	-4.2604	-2.11
U5	-2.0365	0.0761	-3.0801	0.1912	-2.762	0.0104	-1.8088	-0.2653

Bootstrapping relies on random sampling of the available data to triple the test population size in an attempt to learn more about the data (Moore, McCabe, & Craig, 2009, p. 810). Table 4.1 showed the average response values for performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC), price value (PV), and habit (HT) in round 2 were lower than the average response values from round 1. These average response values ranged from 0.111111 to 0.916667 points lower on the Likert scale than the previous round of responses. After increasing the population size, table 4.2 showed significant decreases in the engineers’ responses for survey questions PE3, EE1, EE2, EE3, EE4, FC1, FC3, HT1, and HT2. This data rejected hypotheses H1, H2, H4, H6, and H7, for this testing period, because significant increases did not exist for any survey items associated with PE, EE, FC, PV, or HT. The average response for social influence in round 2 was 0.185185 points higher on the Likert scale compared to the average response from round 1. After bootstrapping the data, significant increases in response values existed for SI1 and SI3. This data partially supported hypothesis H3 for this testing period. Only partial support is achieved because a significant increase does not exist for SI2 which had a p-value of 0.136. The average response for hedonic motivators (HM) in round 2 was 0.111111 points lower on the Likert scale compared to the average responses from round 1, illustrated in table 4.1. However, hypothesis H5 was still rejected, for this testing period, because the p-values for HM1, HM2, and HM3 were all above 0.05 and this decreases was not significant. Finally, in round 2 the average response value for behavioral intentions (BI) was 0.296296 points lower on the Likert scale while average response values for use (U) was 1.844444 points lower on the Likert scale, compared to the response values from round 1. Table 4.2 only reported significant decreases for U1, U2, U3, U4, and U5. This data rejected hypothesis H8, for this testing period, because significant increases did not exist for BI or U and acceptance of the AR technology could not be supported after 5 week of exposure to the AR platform.

4.2 Round 2 vs Round 3

By comparing the results from round 2 and round 3 this thesis could illustrate how the perceive value of this AR platform changed with extended exposure to the technology. This information was important because it was not based on the expected perceived value reported in the survey from round 1. Instead, this testing period compared the engineers' responses after they had experienced the functionality of the AR technology and could make educated judgements towards the perceive value of this AR platform. Table 4.3 showed the average response and average difference in responses for each construct, calculated in the same fashion as table 4.1. 12 of the 13 participants completed a survey for the third round of surveys; 10 participates completed a survey for the second round of surveys. Once again only the 10 participants who responded to both rounds of surveys were used for this comparison.

Table 4.3 Average Survey Responses Round 2 vs Round 3

	R2 AVERAGE LIKERT VALUE	R3 AVERAGE LIKERT VALUE	AVERAGE DIFFERENCE
PE	-0.325	-0.6	-0.375
EE	0.475	0.225	-0.25
SI	-0.4	-0.73333	-0.333333
FC	0.8	0.55	-0.133333
HM	0.933333	0.333333	-0.666667
PV	-0.45	-0.45	0
HT	-1.833333	-1.425	0.4
BI	-0.333333	-0.56667	-0.233333
U	-2.22	-2.36	-0.14

The t-values, p-values, and confidence intervals calculated from the t-test analysis of round 2 versus round 3 are shown alongside the recalculated values, after bootstrapping techniques were applied, in table 4.4.None of the survey items reported significant changes with only 10 participants but tripling the test group told a different story.

Table 4.4 T-test Analysis of Round 2 vs Round 3

	T (N=10)	P-VALUE	LOWER BOUND	UPPER BOUND	T (N=30)	P-VALUE	LOWER BOUND	UPPER BOUND
PE1	-0.9370	0.3732	-1.3657	0.5657	-2.6595	0.0126	-1.1793	-0.154
PE2	-0.2182	0.8321	-1.1367	0.9367	-1.7012	0.9961	-1.0277	0.0944
PE3	-0.647	0.5338	-1.7986	0.9986	-2.2295	0.0337	-1.6617	-0.7162
PE4	-1.6164	0.1405	-1.4397	0.2397	-5.2155	1.393E-5	-1.5314	-0.6686
EE1	-1	0.3434	-0.6524	0.2524	-1.9886	0.0563	-0.4057	0.0057
EE2	-1.1767	0.2695	-1.169	0.369	-0.895	0.3781	-0.5475	0.2142
EE3	-0.3612	0.7263	-0.7264	0.5264	1	0.3256	-0.1045	0.3045
EE4	-0.669	0.5203	-1.3145	0.7145	-1.8571	0.0735	-0.9106	0.0439
SI1	-2.2361	0.0522	-1.0058	0.0058	-4.5717	8.328E-5	-0.8202	-0.3132
SI2	-0.8955	0.3938	-1.0578	0.4578	-4.2868	0.0002	-0.7878	-0.2789
SI3	-0.6883	0.5086	-0.8574	0.4574	-2.4833	0.0190	-0.6686	-0.0647
FC1	0.2182	0.8321	-0.9367	1.1367	-0.1405	0.8892	-0.5185	0.4519
FC2	-1.4056	0.1934	-0.7828	0.1828	-1.1534	0.2582	-0.4622	0.1289
FC3	-0.6883	0.5086	-0.8574	0.4574	-1.9746	0.0579	-0.5429	0.0095
FC4	-1.6164	0.1405	-1.4397	0.2397	-4.397	0.0001	-1.1721	-0.4279
HM1	-2.058	0.0697	-1.6794	0.0794	-5.2155	1.39E-5	-1.5314	-0.6686
HM2	-1.5	0.1679	-1.5049	0.3049	-4.1565	0.0003	-1.3926	-0.4741
HM3	-1.6164	0.1405	-1.4397	0.2397	-3.6942	0.0009	-1.2423	-0.3571
PV1	0.4523	0.6618	-0.8004	1.2004	-1	0.3256	-0.7106	0.2439
PV2	-0.4523	0.6618	-1.2003	0.8004	-3.0104	0.0054	-1.1196	-0.2137
HT1	0.4523	0.6618	-0.8004	1.2004	0.39171	0.6981	-0.4221	0.6221
HT2	1.3093	0.2229	-0.2911	1.0911	1.7951	0.0831	-0.0418	0.6418
HT3	1.765	0.1114	-0.169	1.369	3.4709	0.0016	0.261	1.0065
HT4	0.9370	0.3732	-0.5657	1.3657	1.0523	0.3013	-0.2516	0.7849
BI1	-1.4056	0.1934	-1.5657	0.3657	-2.4733	0.0195	-1.0962	-0.1038
BI2	-0.2641	0.7976	-0.9564	0.7564	-2.6589	0.0126	-1.2384	-0.1616
BI3	0	1	-0.826	0.826	-0.4741	0.639	-0.5314	0.3314
U1	-0.7093	0.4961	-1.2568	0.6568	-1.8482	0.0748	-0.9831	0.04975
U2	0	1	-0.5841	0.5841	0.5708	0.5725	-0.1722	0.3055
U3	0.2641	0.7976	-0.7564	0.9564	3.8079	0.0007	0.1543	0.5124
U4	-0.3015	0.7699	-1.7005	1.3005	3.8079	0.0007	0.1543	0.5124
U5	-0.4611	0.6557	-1.7719	1.1719	2.9709	0.0059	0.0727	0.394

After increasing the size of the test group, performance expectancy (PE) and social influence (SI) reported significant decreases in all of the survey items related to these key determinants, with the exception of PE2 which has a p-value of 0.9961 indicating no significant change in responses for this question. This data rejected hypotheses H1 and H3 which stated that there would be significant increases for these key determinants. No significant changes were reported for survey responses related to effort expectancy (EE) This data rejected hypothesis H2 as no significant increases were evident for this testing period. On average, response values for facilitating conditions (FC) were 0.133333 points lower on the Likert scale between 5 and 10 weeks of exposure to this AR platform. This change was significant for FC4 which had a p-value of 0.0001 and close to significant for FC3 with a p-value of 0.0579. Significant changes in response value between round 2 and round 3 were not observed for FC1 or FC2. This data rejected hypothesis H4, for this testing period, which stated that there would be significant increases in response values for facilitating conditions. Table 4.4 showed that hedonic motivators (HM) experienced extremely significant decreases in all reported values with p-values ranging from 0.0009 to 0.0000139. This data supported hypothesis H5 which stated that significant decreases would exist for this key determinant. The engineers' survey responses for price value (PV) experienced significant decreases for PV2 but changes in response for PV1 were not significant. This data rejected hypothesis H6 as significant increases in response values for PV did not exist. Table 4.3 showed that average response values for habit (HT) were 0.4 points higher on the Likert scale between round 2 and round 3 of surveys. This increase was significant for HT3 but was not significant for any other survey item associated with habit. This data partially supported hypothesis H7 for this testing period which stated that there would be significant increases in response values for HT. Average response values for behavioral intentions (BI) were 0.233333 points lower on the Likert scale for this testing period and this decrease was significant for BI1 and BI2 but was not significant for BI3. In the comparison of round 2 and round 3 U3, U4, and U5 reported significant increases in response values. However, as this was not parallel with the average response values in table 4.3 nor with the theories supported in UTAUT, this was likely a fallacy of the bootstrapping process. This data rejected hypothesis H8 and acceptance of the AR technology could not be supported for this testing period.

4.3 Round 1 vs Round 3

The analysis of differences between responses in round 1 and round 3 was considered a final outcome of this study. This comparison illustrated the changes in perceived value based on the responses from the initial expected value of the AR technology to the final perceived value. This comparison was also the most accurate description of changes in perceived value because this comparison was able to make use of the largest number of viable datasets, providing the best representation of all participants in the study. Table 4.5 showed the average response and average difference in responses for each item in the survey, calculated same as the others, and again only the 11 participants who gave responses for both round 1 and round 3 of testing were included in this comparison.

Table 4.5 Average Survey Response Round 1 vs Round 3

	R1 AVERAGE LIKERT VALUE	R3 AVERAGE LIKERT VALUE	AVERAGE DIFFERENCE
PE	0.477273	-0.59091	-1.068182
EE	1.090909	0.363636	-0.727272
SI	0	-0.45455	-0.45455
FC	0.863636	0.613636	-0.15152
HM	0.933333	0.393939	-0.666667
PV	0.045455	-0.18182	-0.22727
HT	-0.75	-1.29545	-0.54545
BI	0.212121	-0.42424	-0.666667
U	-0.74545	-2.29091	-1.545454

The comparison of round 1 to round 3 reported an over-all decrease in perceived value. This over-all reduction resulted from a combination of the negative responses that were shown in the comparison of round 1 to round 2 with the added amplification outlined in the comparison of round 2 to round 3. Table 4.5 showed there was an overall decrease, ranging from -0.151 to -1.545, for all survey items after 10 weeks of experience working with this AR platform.

The t-values, p-values, and confidence intervals calculated from the t-test analysis of round 1 versus round 3 were shown alongside the recalculated values, after bootstrapping techniques were applied, in table 4.6. These values provided some of the highest levels of significance between the expected and perceived value within a 95% confidence interval, particularly relating to survey items pertaining to use, and best represented the significant changes between expected and perceived value held by the engineers in this test population.

Table 4.6 T-test Analysis Round 1 vs Round 3

	T (N=11)	P-VALUE	LOWER BOUND	UPPER BOUND	T (N=33)	P-VALUE	LOWER BOUND	UPPER BOUND
PE1	-1.715	0.1171	-2.090	0.272	-2.7885	0.00884	-0.942	0.209
PE2	-1.6583	0.1282	-2.344	0.344	-2.0079	0.05316	-1.465	0.0105
PE3	-2.0204	0.07093	-2.485	0.121	-3.9491	0.000404	-1.975	-0.631
PE4	-2.1372	0.05831	-2.414	0.0502	-3.0187	0.004953	-1.624	-0.315
EE1	-0.9273	0.3789	-2.176	0.904	-1.664	0.1054	-1.279	0.128
EE2	-0.8554	0.4124	-1.966	0.875	-1.3047	0.2013	-1.164	0.255
EE3	-1.218	0.2512	-2.315	0.679	-3.2015	0.003084	-1.835	-0.408
EE4	-1.1656	0.2708	-2.647	0.829	-2.6577	0.01218	-2.034	-0.269
SI1	-1	0.3409	-1.761	0.67	-0.58243	0.5644	-0.818	0.454
SI2	-1	0.3409	-1.467	0.558	-0.86964	0.391	-0.81	0.325
SI3	-0.74023	0.4762	-1.458	0.731	-0.62661	0.5354	-0.773	0.409
FC1	0.16621	0.8713	-1.128	1.31	0.30353	0.7635	-0.519	0.701
FC2	-0.71383	0.4917	-1.499	0.771	-2.0863	0.04501	-1.078	-0.013
FC3	-0.45408	0.6595	-1.074	0.71	-1.0339	0.3089	-0.72	0.235
FC4	-1.322	0.2156	-1.465	0.374	-2.0886	0.04478	-1.018	-0.127
HM1	-1.2076	0.255	-1.81	0.538	-2.4022	0.02227	-1.232	0.101
HM2	-1.2681	0.2335	-2.005	0.551	-2.6476	0.01248	-1.394	-0.182
HM3	-1.1699	0.2692	-1.848	0.576	-2.0547	0.04815	-1.207	-0.005
PV1	-0.60733	0.5572	-1.273	0.728	-1.2825	0.2089	-0.863	0.196
PV2	-0.36274	0.7244	-1.299	0.935	-1.0559	0.2989	-0.888	0.281
HT1	-1.3988	0.1921	-2.121	0.485	-2.626	0.01314	-1.507	-0.19
HT2	-1.4368	0.1813	-1.855	0.4	-2.5941	0.01419	-1.352	-0.163
HT3	-0.55902	0.5884	-1.36	0.814	-0.12823	0.8988	-0.512	0.451
HT4	-0.71383	0.4917	-1.499	0.771	-0.85162	0.4008	-0.719	0.295
BI1	-0.87519	0.402	-1.934	0.843	-1.875	0.06994	-1.328	0.055
BI2	-1.8448	0.09485	-1.806	0.17	-2.4142	0.02166	-1.061	-0.09
BI3	-1.1699	0.2692	-1.848	0.576	-1.5061	0.1418	-1.069	0.16
U1	-1.1942	0.26	-2.345	0.708	-3.6025	0.001054	-2.514	-0.698
U2	-1.7889	0.1039	-2.45	0.268	-4.0179	0.000333	-2.055	-0.672
U3	-2.681	0.02306	-3.829	-0.353	-6.2318	5.57E-7	-3.377	-1.713
U4	-2.6343	0.02497	-4.363	-0.365	-6.4732	2.779E-7	-4.103	-2.139
U5	-1.6792	0.124	-3.173	0.446	-3.1881	0.003195	-2.285	-0.503

P-values calculated from the initial 11 viable datasets report that only U3 and U4 showed a significant change between round 1 and round 3 of surveys. This resulted in a rejection of the t-test's null hypothesis indicating significant decreases in use. However, the t-test results after applying bootstrapping methods were still somewhat split. Twelve items from the survey (EE1, EE2, SI1, SI2, SI3, FC1, FC3, PV1, PV2, HT3, HT4, and BI3) had p-values above 0.05. There was not enough information from this data to reject nor confirm the null hypothesis for these items. The p-value calculated for BI1 was also above a significant value but at 0.06994 it was very close to rejecting the t-test's null hypothesis indicating a significant decrease in behavioral intentions to use the AR technology in the future. The remaining 19 survey items showed p-values that rejected the t-test's null hypothesis, indicating a significant change in the engineer's survey responses. All 19 of these significant changes reported a reduction in the perceived value associated with their survey items. This data supported H5 which states that there would be a significant decreases in response values for hedonic motivators (HM) as participants became accustomed to using the AR technology over time. This data rejected hypotheses H1, H2, H3, H4, H6, H7, and H8, as significant increases in response values did not exist and an acceptance of the AR technology was not supported.

4.4 Correlation of Moderators

The moderation of key determinants effect on behavioral intentions, as well as the moderation of behavioral intentions on use were introduced and supported by existing technology acceptance research (Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, 2012), shown in figure 2.1. A correlation table was constructed to find relationships between key determinants and each participant's age, gender and experience, in order to support existing technology acceptance research. The correlation coefficients for this analysis were shown in table 4.7. For this analysis gender needed to hold a numeric value in order to calculate covariance; therefore males were given a value of zero and females were given a value of one. The negative correlation coefficients seen in table 4.7 indicated that females generally reported lower values for each key determinant, with the exception of hedonic motivators. Due to the small size of this test population it was difficult to detect small effects from moderators, therefore large correlation values were needed to support the expected influence. By convention, a correlation value above 0.5 represented a strong relationship (Moore, McCabe, & Craig, 2009, p. 169). The covariance between key determinants and moderators was relatively weak in most situations, but there were some situations that deserve further analysis. By plotting the participant responses over the moderating variable and comparing the results to the expected influence of the moderator, this study could determine if the expected moderation was supported.

Table 4.7 Correlation Coefficients of Moderators

	AGE	GENDER	EXPERIENCE
PE	-0.0306	-0.2	-
EE	0.102	-0.076	0.043
SI	0.147	-0.118	0.143
FC	0.182	-0.22	0.155
HM	-0.098	0.0466	-0.24
PV	-0.052	-0.313	-
HT	0.228	-0.643	0.186
BI	-	-	0.119

As stated in existing technology acceptance research, performance expectancy was expected to be moderated by both gender and age such that it would have a greater effect on younger males. (Venkatesh, Morris, Davis, & Davis, 2003, p. 449; Venkatesh, 2000). Figure 4.1 showed the scatterplot distribution of average PE responses over participant age and gender respectfully. The age based scatterplot showed that all participants 40 years old and above reported an average PE response of zero or higher, with the exception of one participant who had an average PE response of -3. This exceptionally low response was likely responsible for the negative correlation coefficient associated with PE for both age and gender. Additionally, figure 4.1 showed that response values for PE had a wide range regardless of age or gender. Because of this information, there was not enough data to support the expected moderation. This data rejected hypothesis H9 that stated the effects of performance expectancy on behavioral intentions would be moderated by age and gender such that it would have a greater effect on younger males.

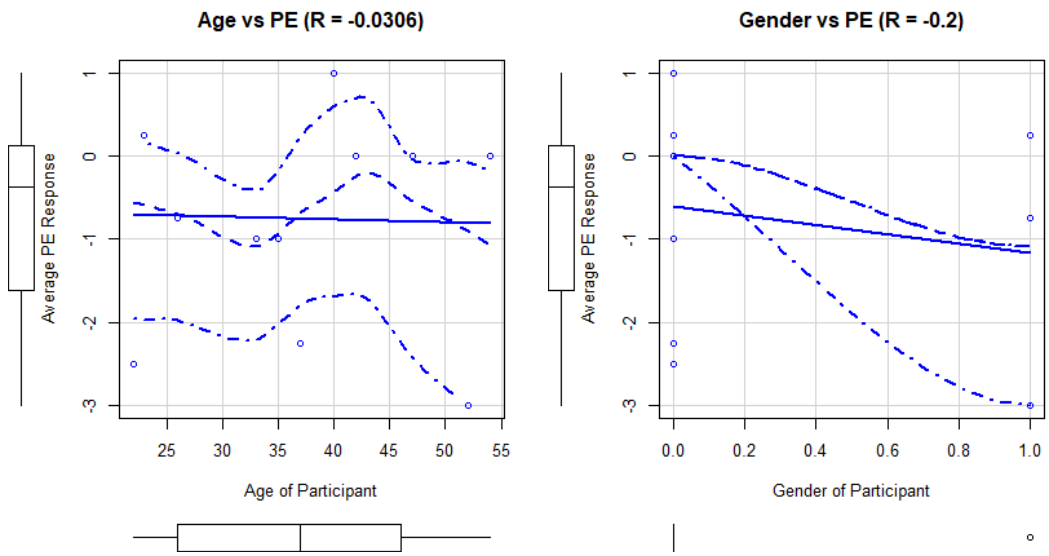

Figure 4.1 Age and Gender Scatterplots for PE

Effort expectancy was predicted to be moderated by age, gender, and experience such that it would have a greater effect on younger females with less experience. In this study the correlation values between EE and its moderators were weak and the scatterplots shown in figure 4.2 have response values did not follow any viewable pattern. This study contained little evidence of any correlation at this time, rejecting hypothesis H10.

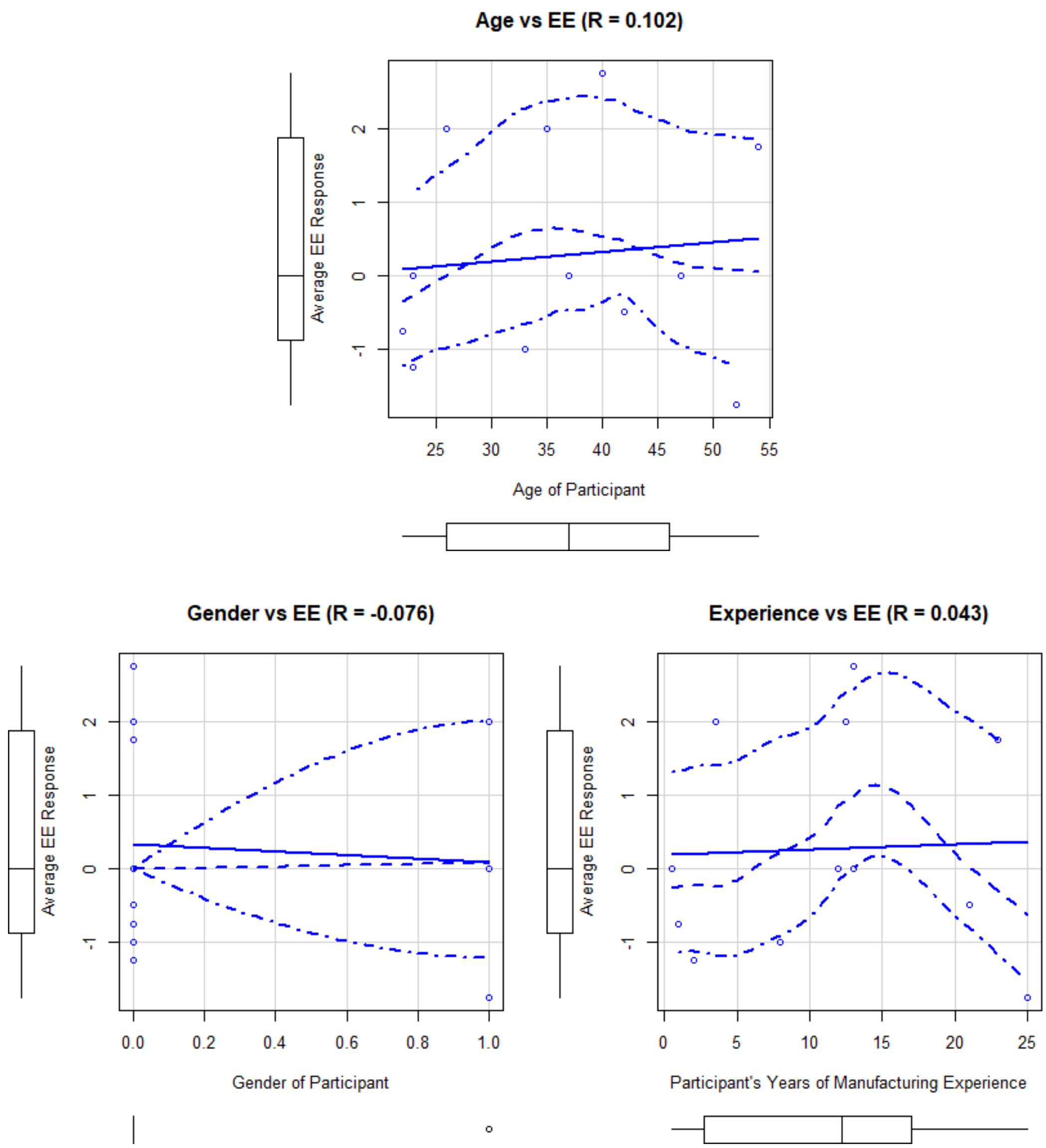

Figure 4.2 Age, Gender, and Experience Scatterplots for EE

Social influence did not have large values for covariance, providing little evidence of moderation, but figure 4.3 suggested there may have been some supported moderation by age, indicated by the clustering of higher reported values near the center of the graph. This data partially supported hypothesis H11 as the effect of SI on behavioral intentions appeared to be greater in older participants, however moderation by gender and experience could not be supported by this study.

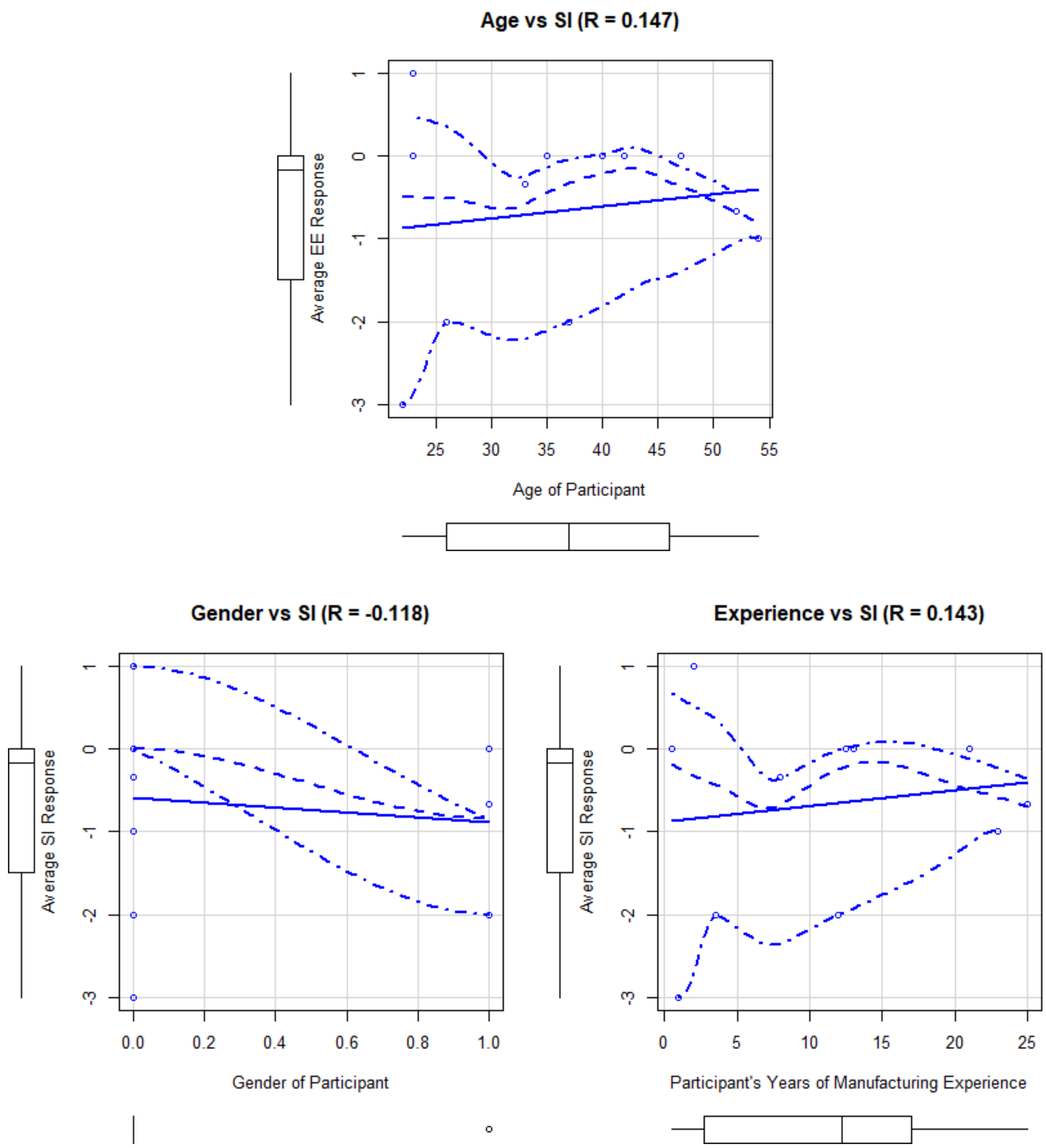

Figure 4.3 Age, Gender, and Experience Scatterplots for SI

Facilitating condition was predicted by existing technology acceptance research to be moderated by age, gender, and experience such that it would be stronger in older females with more experience. Figure 4.4 showed that the response values began to cluster near the middle of the graph much like figure 4.3, however the values then went back down as age and experience grew. Because of this disparity and the low correlation values associated with all moderators, there was not enough evidence to support the expected moderation of facilitating conditions effect on behavioral intentions and hypothesis H12 was rejected.

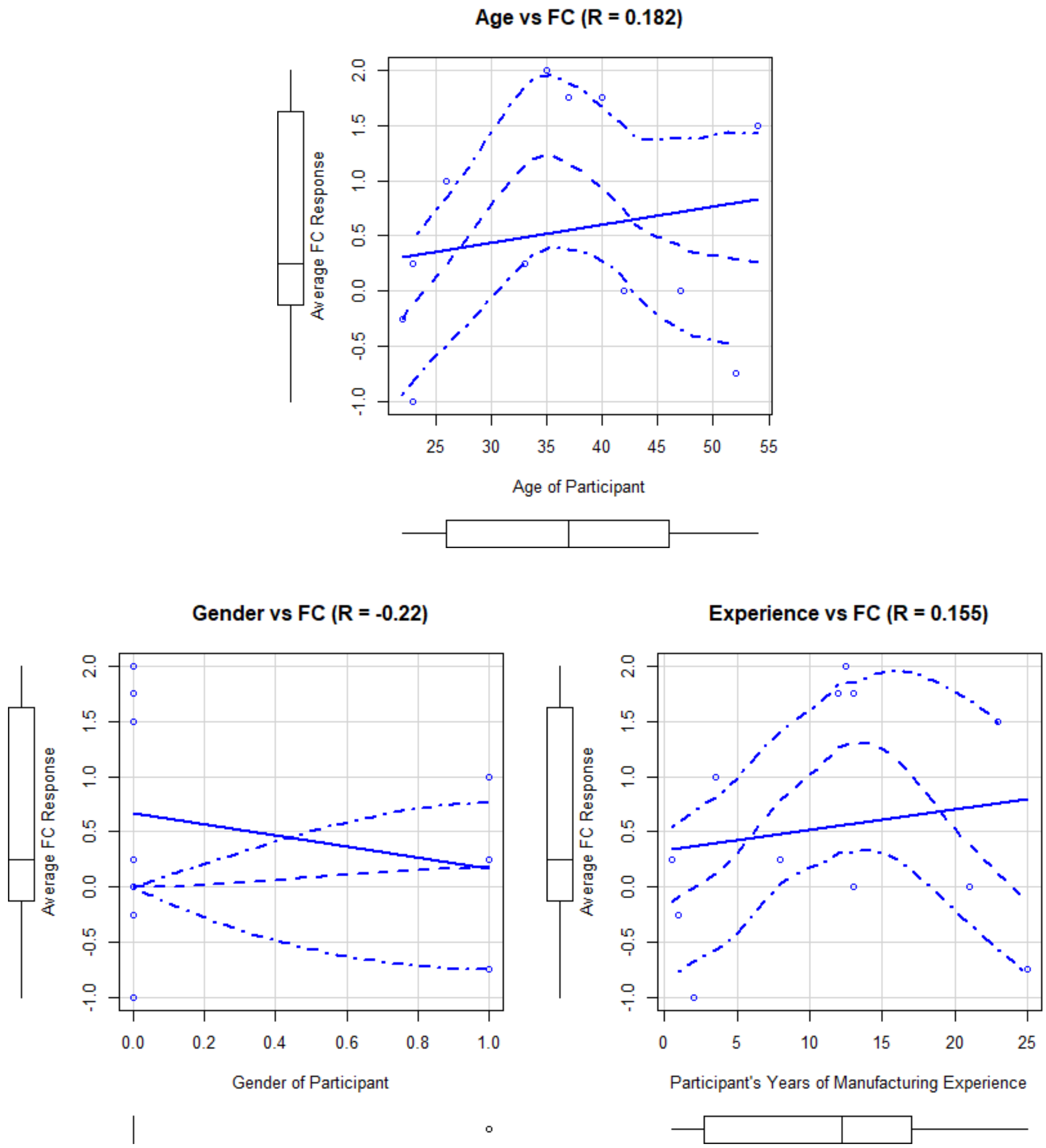

Figure 4.4 Age, Gender, and Experience Scatterplots for FC

Hedonic motivators was expected to be moderated by age, gender, and experience such that it would have greater effect on older males but would decrease as experience grew. The correlation coefficients for age and gender were extremely weak and the scatterplots shown in figure 4.5 showed a wide range of response values regardless of age or gender. The moderation of experience had a relatively higher correlation value, however the distribution of response values did not appear follow a pattern due to the clustering of higher values near the center of the graph. Because of this information hypothesis H13 was rejected as there was not enough data to support the expected moderation by age, gender, or experience.

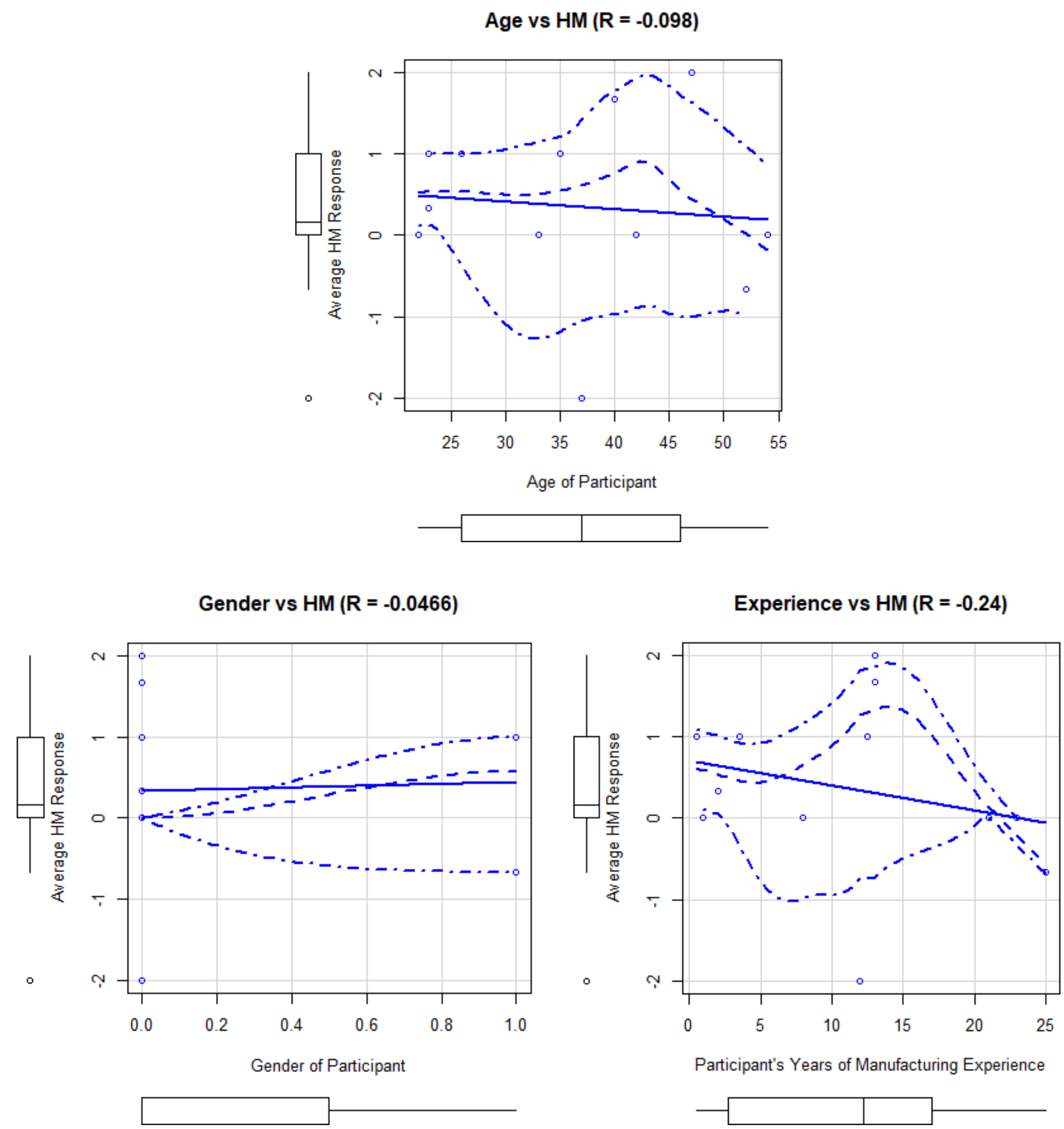

Figure 4.5 Age, Gender, and Experience Scatterplots for HM

Existing technology acceptance research stated that price value was expected to be moderated by age and gender such that it would have greater effect on older females (Venkatesh, 2012), however there was very little evidence from this study to support this. Although the correlation coefficient between price value (PV) and gender seemed to have some magnitude, figure 4.6 showed that there was a wide variety of responses regardless of gender and therefore rejected hypothesis H14.

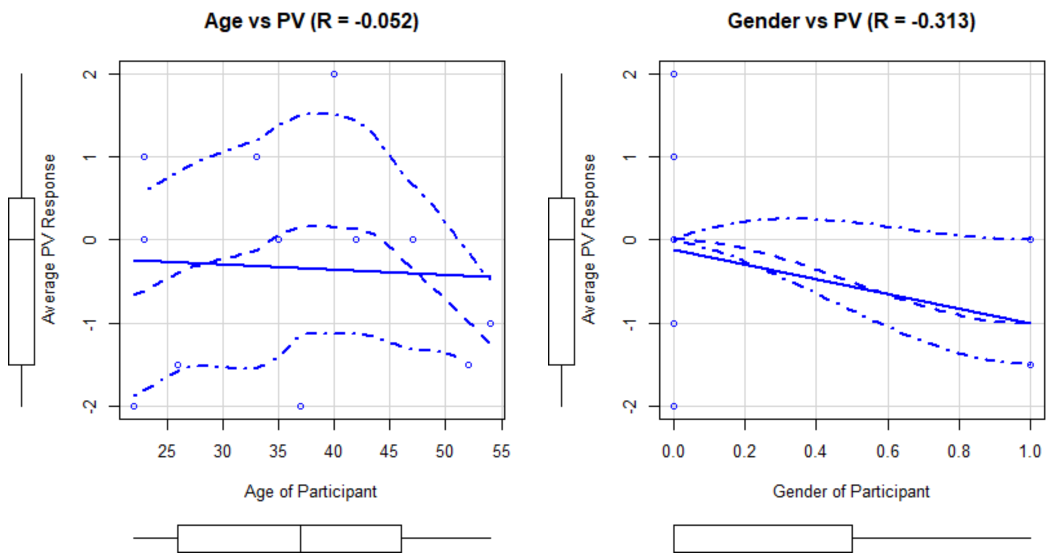

Figure 4.6 Age and Gender vs PV Scatterplots

Table 4.7 showed that habit had the strongest evidence of correlation with gender. Although only 3 of the participants were females all of them reported significantly low values for habit, which could be seen in figure 4.8 by the clumping of responses from the female participants. Habit (HT) was also expected to be moderated by age and experience but, aside from some evidence of slight clumping on the bottom left side of the scatterplots shown in figure 4.8, there was little evidence to support this expectation. This data partially supported hypothesis H15 as there was an apparent relationship between the effects of habit on behavioral intentions and gender.

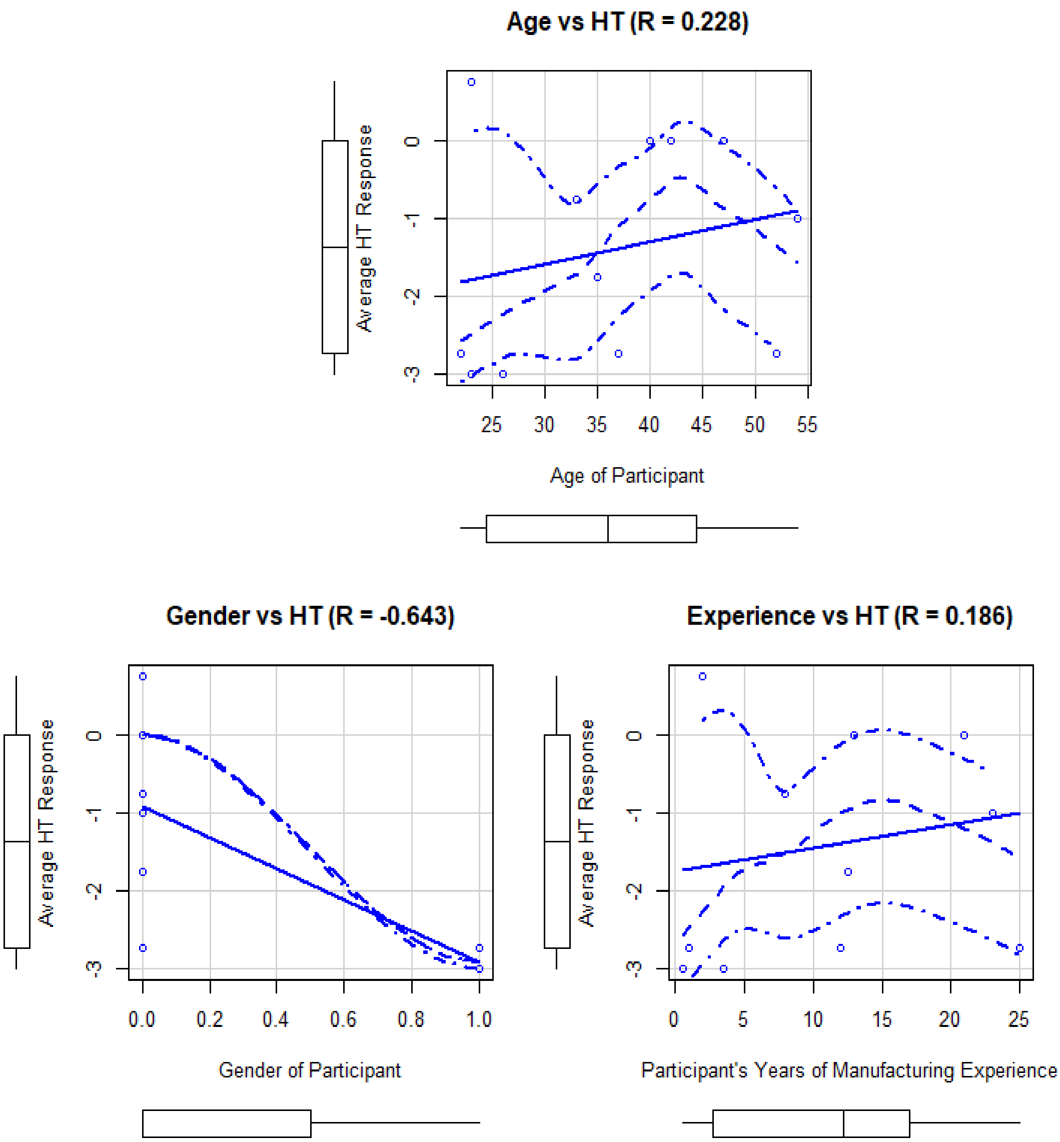

Figure 4.7 Age, Gender, and Experience Scatterplots for HT

Although behavioral intentions was not a key determinant UTAUT predicted that experience would negatively influence the engineers' responses for this construct measurement. The scatterplot distribution of BI responses over years of experience showed in figure 4.8 suggested that users with more experience reported higher values for behavioral intentions. This correlation did not support claims within UTAUT that predicted that users with more experience had less need for the technology and would report lower values for BI. With a correlation coefficients 0.119 the influence experience on behavioral intentions did not appear to be strong, for this study, and hypothesis H16 was rejected.

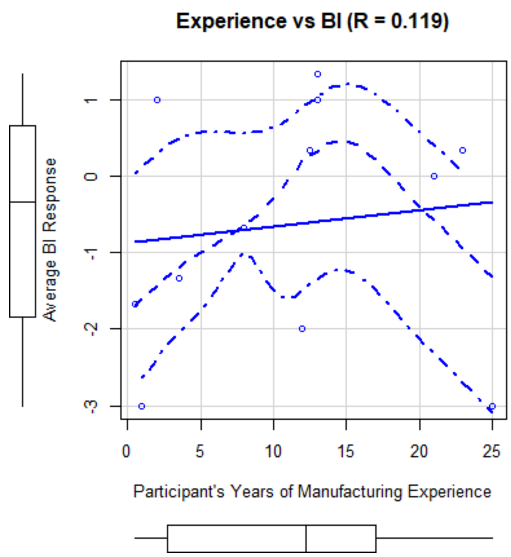

Figure 4.8 Experience vs BI Scatterplot

4.5 Correlation for Key Determinants

Table 4.8 showed the correlation coefficients calculated between each key determinant and behavioral intention to use this AR technology. These values were calculated using the average reported responses from round 3 of the distributed surveys, and showed which key determinants were most related to the engineers' intentions to use this AR platform.

Table 4.8 Correlation Coefficients of Key Determinants

	BI
PE	0.82079524
EE	0.41102107
SI	0.69778796
FC	0.20988462
HM	0.58986149
PV	0.73221076
HT	0.85838892

All of the key determinants reported a positive correlation with behavioral intentions indicating that as the responses under each determinant changed, similar changes would be seen for the intentions to use the technology. As expected, performance expectancy and habit had very strong correlations with behavioral intentions. This confirmed that the technology's ability to improve user performance at work and the habitual use of the technology had a strong relationship with the engineers' intentions to use the technology in the future. Interestingly, price value also showed strong correlations with BI which was not predicted by UTAUT and is unexpected as price value did not report significant changes for most of the comparisons in this study. Effort expectancy, hedonic motivators, and social influence had moderate to strong correlations with BI as predicted by UTAUT and the value between behavioral intentions and facilitating conditions showed a relatively weak correlation indicating that this determinant had less of an influence on the participants' intentions to use this technology in the future. From this information, this study could see which factors motivated the engineers' intended use of the technology and provided insight on what makes an AR platform more acceptable for this test population.

Behavioral intentions should be a strong indication of actual technology use. However, BI and U had a correlation coefficient of -0.081, indicating that as the intentions of use increased the actual use decreased. This suggests that other factors likely influenced the actual use of the AR technology during this study. Reasoning for this adverse correlation was covered in the final chapter of this thesis.

CHAPTER 5. DISCUSSION

The purpose of the augmented reality platform developed for this study was to provide the test population of service engineers with information that was useful for their work tasks and to connect the engineers with remote experts while deployed in the field. The HMT-1 was hypothesized to act as an added tool that would improve the engineers' work performance and provided information on the acceptance and use of AR technology in a manufacturing environment. Chapter five of this thesis provided further interpretation of the data outlined in the results chapter of this thesis. Additionally this chapter discussed why the final results were not parallel with the expected performance and acceptance outlined by previous research (Elia, Gnoni, & Lanzilotto, 2016; Yew, Ong, & Nee, 2016; Uva, 2018), what alterations need to be applied to improve the results if this study is to be replicated, and how this information could be used to prepare enterprise for future application of AR tools.

5.1 Data Interpretation

In the comparison of survey results from round 1 and round 2, the average difference column in table 4.1 showed that all the values related to the acceptance of technology, with the exceptions of social influence (SI), were negative. This indicated that, after exposure to the AR technology, this AR platform did not perform as well as the engineers had initially expected.

Values for performance expectancy (PE), and behavioral intentions (BI) changed from a positive value to a negative value indicating that initially the engineers believed that AR technology would be a valuable addition in these areas but, after 5 week of exposure to the technology, the engineers no longer agreed that the technology held this expected value. This indicates that, on average, the engineers did not believe that this AR platform increased their work performance and did not intend to use this technology in the future. Although this change in opinion was very slight at this stage; it was still worth noting as there was a change from an average positive opinion to an average negative opinion. Values for effort expectancy (EE), facilitating conditions (FC), and hedonic motivators (HM), on average, remained positive for both rounds of surveys. This indicated that after the first 5 weeks of exposure, on average, the engineers still believed that this AR platform had some value in these areas as it was relatively easy to use, they were provided with the necessary tools and knowledge needed to make use of the AR platform, and they found the AR tools enjoyable to use. Average response values for social influence (SI), price value (PV), and habit (HT) were negative in round 1 and remained negative in round 2. There was an increase in the reported value for SI but average opinion towards this key determinant was still negative for this comparison. This indicated that after 5 weeks of exposure to the technology the engineers did not feel motivated by their peers to use the AR platform, did not believe the price of the technology was worth the added value, and had not formed a habit of using the technology. The values reported on Use (U) for round 1 and 2 indicated that, on average, the engineers expected to use this technology once or twice per week. However in the first 5 weeks of exposure the engineers reported using the technology, on average, less than once per week. This may explain the low values and negative average differences as the engineers were reporting based on very little exposure over the first 5 weeks and had not gotten accustomed to using this new technology.

The values reported by the engineers after 10 weeks of exposure continued to show a decrease in perceived value towards this AR platform. This suggested that the opinions recorded in the comparison of round 1 and round 2 were an accurate description of the engineers' perceived value. The survey items that held positive values in round 2 (Effort Expectancy, Facilitating Conditions, & Hedonic Motivators) continued to hold positive values in round 3, however the returns had diminished with extended use. The decrease in average values for hedonic motivators indicated that the novelty of using the AR technology was no longer an added value during the second 5 weeks of exposure to this AR platform. In this testing period behavioral intentions (BI) was a new construct to report significant decreases which would likely have a direct impact on the use of the AR technology. This also meant that, between this comparison and the comparison of round 1 vs round 2, significant decreases in response value had been reported in at least one question for every measurement construct. The responses that had negative averages values (PE, SI, PV, HT, BI, & U) had slightly amplified negative values with the exception of PV and H. The engineer's average opinion of the price value had seen no change from round 2 to round 3, as seen in table 4.3. Habit (HT) was the only determinant to see a positive change in average response values between round 2 and round 3 indicating that the engineers had a better understanding of which situations they would use the AR technology but, seeing as their use had decreased to somewhere between once a week and never, this thesis could assume that the engineers preferred to use their traditional work tools.

Over-all the service engineers' reported a decrease in survey responses related to all constructs of technology acceptance after initial and extended exposure to AR technology. This analysis suggested a significant reduction in acceptance of the AR technology after 10 weeks of experience with this AR platform and allowed this study to make assumptions about the performance of other service engineers similar to our test group, if this study was replicated. The remainder of this chapter discussed what potential factors lead to the rejection of this technology, how this study could be improved for future expansion, and this study's contributions to research on the adoption of AR technology within a manufacturing environment.

5.2 Use Case Selection

There was a significant amount of discussion around importance of use case selection during the 2018 AREA/DMDII AR workshop (Kim, 2018). This importance was supported by personal experience and confirmed that use case selection could severely impact whether an AR application would make it past the pilot study stages of testing. For this study, it was important to apply AR technology in a professional manufacturing environment but this proposed a number of issues when selecting a test group. This was the first attempt at adopting AR technology within the manufacturing organization partnered with this study. Therefore, selection of a test population was limited to the service engineering team which the professional representatives, partnered with this study, had influence over. This group was a small collection of elite engineers with experience investigating a wide variety of product issues which limited the engineers need or ability to take full advantage of the functions provided by this AR platform.

AR technology has proven value in assisting with the execution of "step by step" instructions, (Kim, 2018) however the tasks executed by this test group were not predictable or consistent enough to take advantage of this functionality. Additionally the service engineers in this test group had the skills and experience to complete daily tasks without needing the assistance of this technology. This poor choice of use case likely contributed to the decline in technology acceptance and it can be generalized that other elite services engineering teams would report a similar lack of acceptance due to a lack of need for this technology in its current state. The ideal use case for AR application should be selected from a number of test populations after determining which group would best take advantage of all functions provided by the AR platform. Ideally a test group that performs assembly and disassembly tasks or a test group that is in need of training to complete a task. In addition the ideal use case should have a test population that is larger in size in order to collect more viable data and to make better predictions on the potential use of the AR technology.

5.3 Compatibility with Databases

As discussed previously one major intended function for this AR platform was to provide service engineers with information, but this AR platform was not compatible with all of the databases that the service engineers used. The main database used within this organization has all the information that a service engineer would need; the HMT-1 gained access to this database using a basic web browser. The problem with this database, as reported by the engineers, is that it was very large and somewhat outdated. Over time, the engineering staff had created additional custom databases that allowed them to access the information important to them much faster but these databases had less information in them than the large, outdated, main database. As a result engineers had to search through upwards of 10 different databases in order to find the information they needed and this was a major contributor to this teams issues with accessing valuable data.

Currently there is an effort combine these extra databases into one "data pool" that would replace the outdated database but this effort was still in development and the engineers were still being trained to use this data pool over all the other sources. The HMT-1 was confirmed to be compatible with this new data pool as well; accessing it easily using an onboard application. However, the HMT-1 was not confirmed to work with all other databases in use. This could have led to a situation where this AR platform would not be the easiest way to access information. This lack of performance likely contributed to the decline in technology acceptance and it can be assumed that a general population of service engineers would report a similar lack of acceptance due to this noncompliance with existing tools.

5.4 Availability

A final possible explanation for the observed lack of acceptance of this AR platform was poor availability. Participation in this study may have been severely impacted by a lack of access to the necessary tools required to use the AR platform. This study allowed for six HMT-1 devices to be shared among the entire group of 13 engineers. The service engineers in these teams traveled very frequently and, because the technology was not a proven replacement for other tools, would be required to take the devices with them as an extra item. This could have caused issues if space was limited, especially when traveling by plane, and the engineers could have been force to go multiple weeks at a time without easy access to devices. Furthermore, had an engineer taken a device with them, this would in turn prevent other engineers from having access to that device for the duration of that one engineer’s trip.

Also the HMT-1 was heavily dependent on access to a Wi-Fi signal in order to effectively work. The engineers traditionally carried mobile Wi-Fi hot spots with them but in some remote areas, or large concrete buildings, this would not always provide an adequate signal. Without this necessary resource this AR platform was rendered virtually useless.

Lastly, even if the on-site engineer had everything they needed to make use of the AR platform, if a remote expert was not available at that time, than the on-site engineer could not receive the assistance desired. For this study only a few engineers where assigned the role of remote expert and these engineers still needed to conduct work of their own, making them unavailable to help their fellow colleagues. At least one, or a combination of, of these issue likely contributed to the decline in technology acceptance and it can be generalized that other service engineers who are not prepared appropriately will experience similar results.

5.5 Contributions to Enterprise

One advantage of this study was in the reporting of the development and progress of this study as it was unfolding. These presentations introduced AR technology and its functions to other influential people outside of our test group. Exposing others to AR technology helped to support the need for this technology within a manufacturing environment and produced future use cases so that the technology could be properly applied in other areas.

Furthermore this study illustrated the importance of working with AR developers, who provide software as a service (SaaS), to ensure the AR platform is connected to the existing tools and information already seeded within the organization. This study was a demonstration that, in order to improve performance on a work task, an innovative tool must work in tandem with already existing practices. Organizations could attempt to build their own platforms, with off the shelf hardware and software, but this study was not able to prove that this is a viable path to take. Leading developers in AR software have the skills and experience required to customize their software for the individual needs of an organization. Also, assuming some sort of intellectual property will need to be shared in order to have an AR platform customized for an individual organization, building a partnership with an established AR software company is the best option at this time.

This study also exemplified the preparation needed to effectively adopt innovative AR tools into a manufacturing environment. Organizations should make sure that enough tools are available for all members of a test group as well as ensure a dedicated team of remote experts are available if this is an expected primary function of the AR platform's functionality. Extensive analysis of possible failures within a system may result in additional requirements and expenses needed to incorporate new tools and practices. However, this initial preparation would help to ensure that the AR technology works efficiently.

Finally this study was a strong step forward in the adoption of AR technology for the organization associated with this study. Many business leaders are hesitant to adopt AR technology into an organization due to a natural aversion to risk, the high up-front costs, and a long term ROI (Kim, 2018) but taking the necessary step in order to get a foot in the door was required to find out what works for that organization. There was no evidence that suggested organizations currently working to incorporate AR tools have figured out a perfect solution, but this study was a valuable opportunity to learn what was needed in a relatively safe and controlled environment.

5.6 Conclusion

In conclusion, this study failed to support augmented reality tools as a viable tool for future adoption, within a manufacturing environment. The data indicated that service engineers did not experience increased work performance while using AR technology and that the use and acceptance of this technology decreased after extended exposure to a testable AR platform. This study predicted that a lack of utility and compliance with existing tools contributed to the decrease in the perceived value, experienced by the test population. This study also generalized that, if this study was replicated with a similar service engineering population, similar results would be recorded. This study provided positive contributes towards the initial preparation required when choosing a use case, selecting the appropriate hardware or software, and allocating available resources in order to effectively apply AR technology within a manufacturing environment.

Developments in AR technology are working to cater this technology to a manufacturing environment and suppliers are working to address the needs of their consumers, to create a product that is more easily accepted by the potential users of this technology. Hardware developments are making AR technology more comfortable to wear, are protecting the devices from abrasive working environments, and making devices compatible with existing eye protection regulations and other protective gear, such as hard hats commonly worn in a manufacturing environment. Additionally developments are being made to notify users with flashing lights, loud sounds, or other digital content when the users are near dangerous aspects of the environment they work in, such as pits under a vehicle or large machine with moving parts that could cause injuries (Laughlin, 2018).

Furthermore the AR software being applied to manufacturing environments are working to conform their products to other tools and practices that currently exist within an organizations internet of things (IOT) in order to improve functionality of the AR tools. As organizations move away from paper and into a digital age, cloud storage techniques are being investigated to improve the security of this data and help make this large pool of digital content available through AR technology. Other developments in AR software are investigating the user’s interactions with AR content, investigating the data needs of an organization, adjusting the presentation of this data, and improving the ease of authorization so that organizations can create content that is customized to their internal practices.

Replicating this study with different AR tools or with a different use cases may provide improved values for performance and acceptance but further research is necessary. Initial use cases should involve minimal changes to work processes, address key pain points among a workforce and have traceable metrics that can be used to illustrate the positive contributions of

AR technology. Engaging with internal IT organizations should be implemented to outline desired outcomes, integrate available data sources, address security policies and prepare for post-deployment support (Kim, 2018). This initial preparation helps to develop an informed outlook on the data requirements and investments necessary for effective application of the technology. Current testing of AR technology is investing the technology's functionality to improve engineering design reviews, for virtual prototyping, to assist with on-site inspection tasks, to assist with maintenance tasks, for staff and customer training on new products, to improve manufacturing assembly tasks and for sales productions demonstrations. Positive contributions of AR technology have been recorded in line monitoring cases, process management cases, filed servicing cases, as well as order picking cases (Kim, 2018). These cases have evidence of high acceptance rates as users realize the positive contributions towards productivty associated with AR technology. These positive results should be heavily marketed towards industial leaders and the technology should focus on delivering the best user experience, which address the daily pain points on the job for the industiral workforce, in order to obtain further commitment towards the next phases in the adoption of AR technology.

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APPENDIX A. SURVEY

Experiment Questionnaire

Start of Block: Demographic Information

Q0.1 What is your age?

____

Q0.2 Gender

- ○ Female
- ○ Male
- ○ Do not wish to answer

Q0.3 In years, how long have you worked in a manufacturing environment?

____

End of Block: Demographic Information

Start of Block: Performance Expectancy

Q1 I find Augmented Reality technology useful in my daily life.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q2 Using Augmented Reality technology increases my chances of achieving things that are important to me.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q3 Using Augmented Reality technology helps me accomplish things more quickly.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q4 Using Augmented Reality technology increases my productivity.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Performance Expectancy

Start of Block: Effort Expectancy

Q5 Learning how to use Augmented Reality technology is easy for me.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q6 My interaction with Augmented Reality technology is clear and understandable.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q7 I find Augmented Reality technology easy to use.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q8 It is easy for me to become skillful at using Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Effort Expectancy

Start of Block: Social Influence

Q9 People who are important to me think that I should use Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	

	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q10 People who influence my behavior think that I should use Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q11 People whose opinions that I value prefer that I use Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Social Influence

Start of Block: Facilitating Conditions

Q12 I have the resources necessary to use Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	

	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q13 I have the knowledge necessary to use Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q14 Augmented Reality technology is compatible with other technologies I use.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q15 I can get help from others when I have difficulties using Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Facilitating Conditions

Start of Block: Hedonic Motivation

Q16 Using Augmented Reality technology is fun.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	

	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q17 Using Augmented Reality technology is enjoyable.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q18 Using Augmented Reality technology is very entertaining.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Hedonic Motivation

Start of Block: Price Value

Q19 At $2,000 per headset Augmented Reality technology is reasonably priced.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	

	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q20 Augmented Reality technology is a good value for the money.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Price Value

Start of Block: Habit

Q21 The use of Augmented Reality technology has become a habit for me.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q22 I am addicted to using Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q23 I must use Augmented Reality technology.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q24 Using Augmented Reality technology has become natural to me.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Habit

Start of Block: Behavioral Intention

Q25 I intend to continue using Augmented Reality technology in the future.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q26 I will always try to use Augmented Reality technology in my daily life.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	

	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

Q27 I plan to continue to use Augmented Reality technology frequently.

	Extremely	Mostly	Slightly	Neither	Slightly	Mostly	Extremely	
	-3	-2	-1	0	1	2	3	
Disagree	○	○	○	○	○	○	○	Agree

End of Block: Behavioral Intention

Start of Block: Use

Q28 Please choose how frequently you use Augmented Reality while performing these tasks.

	Never (-3)	Less than once a week (-2)	0 - 1 times per week (-1)	2 - 4 times per week (0)	5 - 7 times per week (1)	At least once per day (2)	Many times per day (3)
Real-time Video Conferencing	○	○	○	○	○	○	○
Delivery of Instructions	○	○	○	○	○	○	○
Note Taking	○	○	○	○	○	○	○
Browse websites	○	○	○	○	○	○	○
Other	○	○	○	○	○	○	○

End of Block: Use

APPENDIX B. FORMS

HMT-1 Initial User's Guide

Log In Information ➡

Atheer App (on device)
Username:
4-digit PIN:
Atheer Website
Username:
Password:

Questions/Troubleshooting Contact:
Drew Berger
xxxxxxx@purdue.edu
xxx-xxx-xxxx

The RealWear HMT-1 is the first ruggedized head mounted Android tablet. With all the functionality of a standard Android tablet, Real-Wear's optimized voice-activated operating system enables hands free work. These instructions will get you started with HMT-1, take you through proper adjustment and fit as well as teach you some basic voice commands. This kit contains one HMT 1 unit, 1 USB c-type cable, 1 wall changer, 2 extra hot-swappable batteries, 2 PPE/Hardhat mounting clips and 1 adjustable head strap.

First the user should determine whether they are left or right eye dominant. To do this:

1. Make a circle with your thumb and first finger (i.e. "ok" hand gesture).
2. With both eyes open look at an object on the wall or in the distance and center it inside the circle.
3. Now close one eye and then the other.

When you close one of your eyes the object will appear to jump outside of the circle. If the object jumps outside of the circle when your left eye is closed then you are left eye dominant. If the object jumps outside of the circle when you're right eye is closed than you are right eye dominant. If you determine that you are left eye dominant you can invert the device and rotate the display on its shoulder joint to bring it underneath the device. Whether you are left or right eye dominant the display should always be hanging beneath the camera.

4. Power the device on by pressing and briefly holding the power button (2-3 seconds should be enough).
5. The display should rest just below your line of sight, you will want to use the shoulder, elbow and wrists joints to adjust the display pod so that you can see the entire screen.

(For more information please review the HMT-1 "Quick Start Guide" included with every device.)

Basic Commands: These global commands can be used at any time while using the HMT-1

Show Help – Speak this command to bring up a list of available commands.

Navigate Home – Speak this command to return to the main home screen.

Navigate Back – Speak this command to return to the last window you viewed.

My Controls – Speak this command to adjust the primary setting on the device.

Mute Microphone – Speak this command to disable the devices microphones, in order to re-enable the microphone just press the textured button located next to the power button.

Dictation – Speak this command when you need to enter a string of text verbally. Without first using the dictation command, you can still enter text but, you will have to enter each letter individually. *additionally Real-Wear has developed a phone app that will allow you to use your cell phone as a keyboard for the device.

Beyond these global commands the HMT-1 follows a basic "see it, say it" policy. This means if you can read it on the screen the device will recognize your command for most applications. For example: From the main menu you can say "My Programs" to open a menu of available applications, then you can say "Chrome" and the device will open a Google Chrome web browser.

Configuration: You will need a computer and internet access in order to reconfigure the device. Reconfiguring your device will allow you to select the desired language, geographic region and time zone as well as connect the device to Wi-Fi. You can also connect to Wi-Fi through the device settings.

1. Open a web browser on your computer, go to **configure.realwear.com** and select "**Configure your HMT-1**".
2. Select the desired language, then select your geographic region and time zone.
3. Next enter the network name (case sensitive) and the network password.
4. Click "**Create Configuration QR Code**".
5. Using the HMT-1 go to **My Programs** > **Configuration**
6. Use the camera on the device to scan the configuration QR code and the device will automatically update.

Document Navigation: You can view photos, videos, or other pdf documents from the "My Files" menu.

1. From the home screen say "**My Files**"
   (The most recently used documents will be displayed on the left side of the screen with three folders to the right.)
2. Say "**My Documents**" to open the documents menu.
3. Use the "**Select Item <number>**" command to select one of the documents for viewing.
4. Use the "**Zoom Level 3**" command to get a closer look.
   (The image opens at zoom level 1 by default and there are up to 5 zoom levels)
5. Once zoomed in move your head left, right, up, and down to move the viewing window around the document.
6. Once you have found what you're looking for use the "**Freeze Document**" command to hold the viewing window in place so that you can freely move your head without losing your position on the document.
7. To regain control of the viewing window say "**Control Document**".
8. Use the "**Navigate Back**" command to select a new document or the "**Navigate Home**" command to get back to the main screen.

Questions/Troubleshooting Contact:
Drew Berger
xxxxxxx@purdue.edu
xxx-xxx-xxxx

Common Issues Among Users

Update Device and Software:

If this is your first time using the device or you have not used the device for an extended period of time, updates may be required for the hardware or software to operate correctly.

1. To update the HMT-1 device simply go **My Programs > Wireless Updates.** From there you can check for any device updates.
2. To update the AiR Enterprise software open the AiR Enterprise app and then use the "**Open settings"** command and "**Check updates"** command to check for any software updates.

Microphone issues:

From time to time the microphone will "sleep" on you if the microphone is not responding to commands trying pressing the textured ACTION button located next to the power button. If it is still not responding turn the device off and then back on.

At any time you can use the "**Mute Microphone"** command and the HMT-1 will stop responding to commands. This should help if commands are being recognized when you did not intend to give a command. This will work during video calls and will not restrict your ability to be heard. To turn the microphone back on, simply press the textured ACTION button located next to the power button.

Entering Text:

Text can be entered one letter at a time using the "**letter/symbol <letter>**" command. Text can also be entered entire strings at a time using the "**Dictation**" command. And last Real-Wear has a cell phone app that will allow you to type out your text and assign it to a QR code that can be scanned by the device.

Turning off the device:

Much like other cellphones or electronic devices most inconsistencies with this device can be resolved by powering the device off and then back on.

****Please remember to HOLD the power button on the device, until a powering off message is displayed, to completely shut it down. If the device is not completely shut down before the end of the day it will drain the battery overnight. ****

It is highly recommended that users take a private 30 minutes to an hours to become familiar with the device. This will help get the user acclimated to the commands and interface without feeling pressure from their surroundings. Check out **"My Programs > My Controls**" from this menu you can adjust the volume, screen brightness, change the Wi-Fi connection and many other adjustments. Check out "**My Camera**", navigate "**My Files**", or get comfortable with Atheer's interface.

If any other issues arise do not hesitate to contact Drew Berger with any concerns. You may contact him using the email or phone number listed at the top of each set of instructions or by video call via the AiR Enterprise software.

Questions/Troubleshooting Contact:
Drew Berger
xxxxxxx@purdue.edu
xxx-xxx-xxxx

AiR Enterprise Script:

Atheer's AiR Enterprise is a 3rd party application that that is designed to connect employee's with remote experts in order to collaborate on difficult tasks via real-time video conferencing.

To open the AiR Enterprise app simply:

1. Go to "**My Programs**", you can turn your head left and right to scroll through the available apps,
2. In the bottom left corner you should see the AiR Enterprise app, say "**AiR Enterprise**" or "**Select Item 2**" to open the application.

When you first open the application all accounts registered to that device will be listed on the screen. From the "**Show Help**" menu you can see that "**Show Commands**" will bring up a list of available commands for this application.

To Log into an Atheer Account:

1. Use the "**Log In <user name>**" command to select the account you want to use.
2. Use the "**Select item <number>**" command to enter the passcode associated with that account. *Numbers are scrambled for security purposes.
3. Say "**Enter**" to submit your passcode

Call Remote Expert:

1. To view a list of available contacts say "**Open Contacts**"
   (If you do not see a list of available contacts you are in the "Message User" page, simply repeat "**Open Contacts**" to view the full list of contacts)
2. Find the appropriate username and use the "**Call <username>**" command to open a call with that account.
3. If the remote expert is available the screen will display a "Ringing…" message, simple wait for them to accept or deny the call.
4. If the remote expert in not online the screen will display a "Calling…" message, in a situation where you are unable to reach the remote expert it is possible to leave a text message for when they return.
5. To close the call say "**End call**".

Message Remote Expert:

1. Open contacts with the "**Open contacts**" command.
2. Use the "**Sort List**" command to see the item numbers associated with each account.
3. Use the "**Select item <number>**" command to select the appropriate user.
4. Use the "**Message User**" command to open the "Message User" page
   (The name of the user will be located on the bottom right side of the screen.)
5. Repeat any of the available messages to enter it into the message box or use the "**Dictate Message**" command and use the devices "talk to text" capabilities to dictate your message.
6. Last use the "**Send Message**" command to send the message.

Remote Expert Initial Guide

Atheer Website
Username:
xxxxxxxxxx@gmail.com
Password: xxxxxxxxxx

Atheer App (on device)
Username: xxx xxxxxx xxxx
4-digit PIN: xxxx

Questions/Troubleshooting Contact:
Drew Berger
xxxxxxx@purdue.edu
xxx-xxx-xxxx

Logging in:

Go to https://airsuite.atheerair.com to log in using your designated username and password.

On the left hand side of the screen you should be able to see any users currently online.

Call or message a HMT-1 User:

Select any user you need to interact with from the list of online users.

Once a specific user is selected you can conduct a remote video call using the icon located next to the user's name near the center of the top of the screen.

Send quick messages to the HMT-1 User using the message board directly below the call button.

During a call, from the web end you are able to:

- Toggle on/off your web camera.
- End the video call
- Make annotations over-top the video feed.
- View the call in full screen.
- Control the flashlight on the HTM-1 user's headset.

Questions/Troubleshooting Contact:
Drew Berger
xxxxxxx@purdue.edu
xxx-xxx-xxxx

Common Issues Among Users

There are less troubleshooting issues with the web side compared to the device side.

If the video quality is poor it is most likely an issue with the Wi-Fi connection on the device side or with the lighting on the device side.

There is no zoom function available from the web side or through Atheer's functionality at this time. There is however a zoom function on the device's camera which can be used to take pictures and video to be viewed at another time.

The ability to annotate over the field users point of view is a one the most valuable functionalities on this platform, use it to your advantage whenever you can. However, please keep in mind that the color chosen for annotations is difficult to see at times. It is good practice to check with the field user after each annotation to make sure they see any additions you have made.

Other functions of this website include:

Creating simple task flows for assistance in the Field

Sending task flows to HTM-1 Users

Upload files (.doc, .pdf, .jpeg, etc.) to any online user's account.

If any other issues arise do not hesitate to contact Drew Berger with any concerns. You may contact him using the email or phone number listed at the top of each set of instructions or by video call via the AiR Enterprise software.